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AD-A236 094

IDA PAPER P-2516

CONCURRENT ENGINEERING TEAMS

Volume II: Annotated Bibliography

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20030214083

November 1990

Prepared for
Office of the Under Secretary of Defense for Acquisition
(Research and Advanced Technology)

Supported by
Air Force Human Resources Laboratory
Wright-Patterson AFB, Ohio

INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

IDA Log No. HQ 90-36608

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
November 1990

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Concurrent Engineering Teams, Volume II: Annotated Bibliography

5. FUNDING NUMBERS
C-MDA 903 89 C 0003
TA-T-D6-554

6. AUTHOR(S)
Karen J. Richter and David A. Dierolf

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Paper P-2516

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of the Under Secretary of Defense for Acquisition
The Pentagon
Washington, DC 20301

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Specific concurrent engineering practices vary among organizations. There are, however, various management practices that appear to work well for most organizations. This paper presents the reader with specific, useful examples from several defense contractors illustrating how multifunctional concurrent engineering teams are being organized and managed and how concurrent engineering team meetings are conducted and supported. The types of computer support that could be used to enhance the efficiency and effectiveness of concurrent engineering team meetings are identified.
The general findings are that there exists a direct relationship between total quality management (TQM) and concurrent engineering, and that many applications of computer-aided group problem solving are possible and practical today for the concurrent engineering team meetings. Areas identified for additional research are the documentation of the decision process and rationale during the product and process definition, the capturing of lessons learned during the implementation of concurrent engineering, and the performance evaluation and training of team members.

14. SUBJECT TERMS
Concurrent engineering, integrated product development, product and process definition, multifunctional teams, group problem solving, team meetings, Total Quality Management (TQM), team management, organizational design

15. NUMBER OF PAGES
126

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

IDA PAPER P-2516

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INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 89 C 0003
Task T-D6-554

VOLUME II
CONTENTS

TOTAL QUALITY MANAGEMENT

TOTAL QUALITY MANAGEMENT

PAPERS/PRESENTATIONS

Aaron, Robert D., "What Processes do You Own? How are They Doing?," *Program Manager*, Journal of the Defense Systems Management College, September-October 1989, pp. 17-21.

Aerospace Industries Association, pamphlet on Total Quality Management, 1990.

Alexander, Col. Roger S., USAF, "Total Quality Management, The ASD Experience," *Proceedings of the IEEE 1989 National Aerospace and Electronics Conference*, NAECON 1989, Volume 4, pp. 1655-1660.

> TQM can be described as a leadership philosophy that creates a working environment which promotes teamwork and the quest for continuous improvement. The Aeronautical Systems Division (ASD) has been engaged in applying this philosophy for two years. This paper summarizes the evolution and operation of TQM at ASD and then discusses the lessons being learned.

Anderson, Bruce, Tektronix Automotive Business Unit, "Accounting for Continuous Improvement," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Andrews, Don, Dow Chemical Canada, Inc., Hoshin Planning, Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Andrews, Don, Dow Chemical Canada, Inc., Developing a Company Wide TQM Master Plan, Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Appleton, Herbert M., Martin Marietta Missile Systems, "Measuring the Cost of Quality of Business Processes," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 198-203.

> This paper presents arguments for analysis and measurement of processes that control organizations. All activities in a business process have either a direct or indirect effect on service and quality within the organization which ultimately is passed on to the customer in the form of higher costs or against the organization's profit line. Today, a majority of the costs of quality, nonconformance and poor service is generated by indirect labor as opposed to direct-touch labor. Applying enhancements of classical Industrial Engineering work measurement tools in a team of interfunctional, experienced "knowledgeworkers" provides monitoring tools to measure the cost of quality and breakthroughs to simplify and improve the process.

Atwood, Donald J., The Deputy Secretary of Defense, "DoD Strives for Total Quality Management," *Signal*, January 1990, pp. 25-26.

Atwood, Donald J., The Deputy Secretary of Defense, *Improving the Acquisition Process--Buying Best Value*, Memorandum, 1 May 1989.

Augustine, Norman R., "Industry and Total Quality Management," *Signal*, January 1990, page 37; *Current News Special Edition No. 1838*, March 1990, page 5.

Barry, Dominick R., Martin Marietta Astronautics, "Total Quality Management: Cultures for Improved Productivity," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 209-213.

This paper addresses three crucial areas vital to the success of Total Quality Management: (1) the development of an organizational culture which is adaptive in an increasingly turbulent environment; (2) the role of management in providing goals and consistent visible support for the changes required to meet today's new challenges; and (3) creation of a reward system which gives continuous life to TQM.

Bauer, Dr. Lawrence T., Harris Corporation, "Total Quality Management Planning," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 214-216.

The key ingredient to any successful TQM program is top management commitment and involvement. The early top management involvement reflects itself in a series of goals and visions for the organizations. From these broad guidelines, awareness training of personnel can take place, followed by a selected level of skills training associated with the process of improvement and changing the culture of the organization. Management training must also be considered to include continuous improvement as another tool in the manager's kit of approaches to the business environment. To track the success of the program, it is appropriate that a series of measurements be determined reflecting the results of the teams pursuing process improvements. To maintain and coordinate the program, the issue of a responsible person or executive in charge is also appropriate. Following a series of early successes, most programs will tend to level out or even drop in their effectiveness. It is necessary to recognize that TQM requires certain planning for the next level of attainment and the long term infusion of TQM into the culture.

Bebb, H. Barry, "Quality Design Engineering, The Missing Link in U.S. Competitiveness," Xerox, Viewgraphs, edited by Gary Slutsker.

One way to keep up with Japanese automakers is with quality circles and company songs. Another, and possibly better, technique is to purchase more lasers.

Betti, John A., Ford Motor Company, *The Quest for Quality, A Key to the Corporate Turnaround at Ford Motor Company*, presented to the U.S. Air Force Systems Command and a group of aerospace industry CEOs, Andrews AFB, 4 November 1988.

Betti, John A., Under Secretary of Defense (Acquisition), "Changing the Fundamental Acquisition Process," *Defense Issues*, Volume 4, Number 19, remarks to the fourth Annual Quality Improvement Symposium, Dayton, OH, 12 September 1989.

Blakeslee, Sandara, "Restoring Quality in Quality Control," *The Changing Technology*, *Washington Post*, article.

There is a silver lining to recent disasters in defense industry: a search has been launched for more and better people.

Bowen, Phillip and Ben Davis, Martin Marietta Aerospace, "Total Quality Management as Applied to Space Systems New Build Hardware," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 217-220.

Total Quality Management concepts such as concurrent engineering, product teams, job ownership, vendor involvement and continuous product improvement were implemented in the design and build of two new structural subsystems for one of Martin Marietta's Space System's programs. The practice of these concepts enhanced the engineering and manufacturing efforts, resulting in a drastic reduction in the number of errors and produced a high quality product on schedule and under budget. In addition, the practice of these concepts improved the working environment by encouraging each individual to share responsibility for the success of the product.

Bowman, Capt. Peter, Portsmouth Naval Shipyard, "Continuous Improvement at the Portsmouth Naval Shipyard," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Broedling, Laurie A., Keynote Address, American Society for Quality Control, Fourth Annual Quality Conference, Cocoa Beach, FL, 29 March 1990.

Broedling, Laurie A., "DoD Perspective on Continuous Improvement in Industry," presented at the Defense Communication Agency Forecast to Industry, Crystal Gateway Marriott, Arlington, VA, 17 April 1990.

Bushe, Gervase R., "Cultural Contradictions of Statistical Process Control in American Manufacturing Organizations," *Journal of Management*, Vol. 14, No. 1, 1988, pp. 19-31.

This 2-1/2-year study of the implementation of statistical process control in one U.S. location of a large corporation in the automotive industry uncovered cultural barriers to the innovation. A "manufacturing culture" is posited and three cultural themes that impeded implementation are described. Implications for research on use of innovation and ethnographic inquiry are discussed.

Byrne, Diane M. and Shin Taguchi, "The Taguchi Approach to Parameter Design," *ASQC Quality Congress Transaction*, Anaheim, CA, 1986.

Designing a product and a system to manufacture the product requires innovation. Few countries can compare with the innovation that is bred in the U.S. In fact, the Japanese have been known to latch onto *system designs* which were developed by U.S. scientists and engineers. Consequently, the system design for a given product may be virtually the same in Japan as in the U.S. Why then do the Japanese end up with a better product?

The answer is found in their keen ability to optimize product and process designs through the methodology developed by Dr. Genichi Taguchi. The key element of Dr. Taguchi's optimization procedure is the step called Parameter Design--the determination of product parameters or process factor levels such that the product's functional characteristic is optimized and has minimal sensitivity to *noise*.

This paper offers an introduction to Dr. Taguchi's philosophy and to his systematic approach to quality engineering which essentially includes these three steps: (1) system design; (2) parameter design; and (3) tolerance design. We focus in this paper on the middle step, parameter design, which

is often the most crucial step for achieving high quality without an increase in cost.

Tolerance design typically means *spending money*: buying better grade materials, etc. The Japanese concentrate their efforts on parameter design which usually entails optimizing with low cost materials. They employ tolerance design when the desired quality level cannot be reached through parameter design.

To illustrate the use of the parameter design technique, we discuss a case study where the objective was to maximize the force required to separate a small assembly. Through discussion of this example, several features of the Taguchi methodology are demonstrated, such as orthogonal arrays, and the use of the signal-to-noise ratio in the data analysis. We describe how these tools were used in determining a combination of controllable-factor levels which resulted in maximum pull-off force with minimal influence from changes in uncontrollable (noise) factors. Such is the goal of parameter design.

Carlucci, Frank, The Secretary of Defense, *Department of Defense Posture on Quality*, Memorandum, 30 March 1988.

Cartin, T.J., Northrop Corporation, "Quality - The Old and The New Testaments," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 225-228.

The old testament is TQC as described by Feigenbaum but rarely practiced. The new testament is TQC reformulated with a change in basic philosophy. It is primarily a way to manage, but it is no longer the responsibility of a quality specialist or organization. Its fundamental tenant is continuous process improvement, beyond requirements, and satisfying your internal and external customers.

This new direction results in significant changes in the activities of all employees and organizations including Quality Assurance. Most significantly it adds quality objectives for the entire organization.

Collier, Joe C. Jr., Central Main Power Co., "Customer Satisfaction--Total Quality Will be the Focus for the 1990's," *Transmission and Distribution*, January 1990, pp. 18-19.

Electric utilities are facing a rapidly changing environment. In order to survive, a program of total quality control (TQC) is advised. TQC is a systematic approach to identifying opportunities, solving problems, and making improvements. This process aims at constant improvement and occasional breakthroughs or innovations. The key to TQC is to first determine the customer's valid needs and then to mobilize the entire company to help meet those needs. This results in customer satisfaction. TQC is based on four principles: (1) Focus on the customers; (2) Management by fact; (3) Constant improvement; and (4) Respect for people. The three separate, yet very related, parts of TQC are: (1) Quality improvement teams; (2) Quality in daily work; and (3) Policy deployment. Management should be organized as a lean team that relies on cross fertilization of ideas for setting goals and establishing procedures.

Costello, T.A., General Motors Corp., "A Process for Concept Development," *ICED '89 Proceedings*, Harrogate, UK, August 1989, pp. 35-37.

The integration of state of the art design practices into a comprehensive design process called the Concept Development Process has yielded

significant improvements in product competitiveness within AC Rochester Division of General Motors.

Costello, Dr. Robert, The Under Secretary of Defense for Acquisition, *Implementation of TQM in DoD Acquisition*, Memorandum, 19 August 1988.

Costello, Dr. Robert, The Under Secretary of Defense for Acquisition, *TQM in Acquisition and the Transition from Development to Production*, Memorandum with change to DoD 4245.7-M, 12 January 1989.

Costello, Dr. Robert, The Under Secretary of Defense for Acquisition, *Implementation of Total Quality Management in DoD Acquisition*, Memorandum for Secretaries of the Military Departments, Assistant Secretary of Defense (P&L), and Directors of Defense Agencies, 19 August 1988.

Attachment 1: Definition

Attachment 2: Preparatory Activities and Suggested Readings

Currie, Malcolm, Hughes Aircraft Company, "The Quality Challenge is Simple: Every Day We Have to be Better Than We Were Yesterday," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Danna, Peter and Michael Herrington, Olin Corporation, "Total Quality Management: An Action Project Approach," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 89-97.

Olin has implemented a quality improvement process called TQM. The TQM process begins with top management. In the Chemicals Group, The Quality Steering Team is the Group President's Senior Management Staff, and is chaired by the Group President. Each year, an Annual Quality Plan is developed which includes Quality Action Projects. These Projects are specific actions which will help to achieve the Olin Vision: to be universally recognized as a preferred and innovative supplier of quality products and services, and to have each individual meet the agreed upon expectations of internal and external customers all the time.

Defense Logistics Agency, "Ask One Simple Question of the Customer," *TQM Quarterly*, Volume 1, Number 1, Fall 1989.

The Deming Library, Volume II: The 14 Points, Discussion Guide, Expert Knowledge Systems, Inc., McLean, VA, for the Management Improvement Collaborative, 1987.

Department of Defense (DoD), *TQM Master Plan*, August 1988.

Department of Defense (DoD), "TQM Management Guide, Volume I, Key Features of the DoD Implementation," DoD 5000.51-G, Final Draft, 2 February 1990.

Department of Defense (DoD), *TQM Management Guide, Volume II, A Guide to Implementation*, DoD 5000.51-G, Final Draft, 15 February 1990.

Department of Defense (DoD), *Total Quality Management, An Education and Training Strategy for TQM in the Department of Defense*, Office of the Assistant Secretary of Defense (P&L) TQM/IPQ, Washington, DC, July 1989.

Department of Defense (DoD), Total Quality Management Pamphlet with Carlucci's Memo, Department of Defense Posture on Quality, Washington, D.C., 30 March 1988.

TQM is a DoD initiative for continuously improving its performance at every level, in every area of DoD responsibility. Improvement is directed at satisfying such broad goals as cost, quality, schedule, and mission need and suitability. TQM combines fundamental management techniques, existing improvement efforts, and specialized technical skills under a rigorous, disciplined structure focused on continuously improving all DoD processes. It demands commitment and discipline. It relies on people and involves everyone.

Department of Defense (DoD) Directive (Draft), *TQM*, 16 June 1989.

Department of Defense (DoD) News Release, *DoD Implements TQM*, Office of Assistant Secretary of Defense (Public Affairs), No. 418-88, 18 August 1988.

Department of Defense, Office of the Assistant Secretary of Defense, Production and Logistics, *TQM Fact Sheet*, 26 February 1990.

Dimitroff, Gail R., General Dynamics Space Systems Division, "Total Quality Management and Defense," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp.73-78.

This paper presents the current status of the TQM movement within the DoD and the defense industry and demonstrates implementation strategies as well as impediments to those approaches. There is an emphasis on strategies that span government and industry.

The core of TQM is viewed as a customer-driven strategy for continual improvement, which can also accommodate and integrate innovation. While problems in the past have been addressed in terms of conflict resolution, the new philosophy requires the creation of an environment consonant with cross-functional/cross-institutional problem solving--a major cultural change. The essay also explains the important role TQM will play in enabling defense contractors to compete. The documented history of those companies with existing TQM strategies indicates the tremendous competitive opportunity TQM offers. A brief review of the ramifications is included.

Duffy, Carolyn, "TQM Efforts Mean Survival at ITT Defense: J. Edwards Deming," *Washington Technology, Supplement*, 27 November 1989, article.

Dumas, Roland A., Consultant, San Mateo, CA, "Join Forces for Total Quality Control," *Quality*, May 1989, pp. 24-27.

Many managers and executives see quality systems as techniques to be incorporated into their traditional portfolio of management tools. Quality professionals see such systems as an essential viewpoint in the development of competitive businesses. The experience of those involved suggests that new technologies and new systems are the relatively easy part; getting people to use them is the problem. There needs to be a balance and a planned synergy between new technical systems and the social environments in which they function. To be fully integrated into the way a company operates, a company-wide quality system must be generally accepted as a worthy replacement for the existing, comfortable and well-known way of conducting business. A quality program requires the thoughtful, experienced, and structured guidance of leadership familiar with the process of organizational change.

Elkins, Steve, "Florida Power and Light Participation Systems," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Fargher, John S.W., Jr., *The Dynamics of TQM: Fertile Areas of Research*, Naval Aviation Depot, Cherry Point, NC.

> Led by the Department of the Navy and civilian industry experience, the Secretary of Defense issued a memorandum on 30 March 1988 emphasizing the TQM effort as the vehicle for attaining continuous quality improvement in our operations, and as a major strategy to meet the President's productivity objectives. Attached to this memo was a DoD Posture Statement on Quality, emphasizing a cultural change to require continuous improvement; emphasizing quality and productivity improvement; changing the concept of quality from inspection to designing and building quality into the process; requiring commitment to quality becoming a part of every organization and its personnel; and assigning responsibility to all managers and other personnel to assume responsibility for the quality of their efforts. Earlier, the Department of the Navy began implementation of TQM at several of their field activities. The Naval Aviation Depot, Cherry Point, was recognized as one of the more successful productivity and quality implementations as recognized by selection by QMB as a Quality Improvement Prototype in the President's Productivity Improvement Program, winning the Institute of Industrial Engineer's Award for Excellence in Productivity Improvement, being the first to implement Productivity Gain Sharing (PGS) organization-wide, and the first to receive the Secretary of Defense Award for Excellence in Implementation of TQM.
>
> The purpose of this paper is to (1) present the evolution of the TQM philosophy from statistical process control through artisan participation to management participation, and (2) develop strategies and detail the current model for TQM as fully developed at the DoD's leading edge organization, the Naval Aviation Depot, Cherry Point, North Carolina. Areas requiring further research are also identified.

Feigenbaum, Armand V., General Systems Company, "How to Implement Total Quality Control," *Executive Excellence*, November 1989, pp. 15-16.

> One of the most significant trends in recent marketplace history is the doubling of buyer emphasis on quality. Research indicates that 8 out of 10 customers in 1988 made quality equal to or more important than price in their purchase decisions. Ten years ago, only three to four customers in ten made this choice. Implementation of a quality control system requires understanding of the basic benchmarks of total quality management: (1) Quality is a systemic process; (2) The quality structure should support both individual and team effort; (3) Quality is defined by the customer; (4) Quality is an ethic; and (5) Quality improvement is continuous. The integrated three-phase approach used in implementing a quality control system requires: (1) Analysis; (2) Planning and programming; and (3) Construction and implementation. Investment in quality programs produces higher sales and improvement in quality costs.

Fici, James A., Westinghouse Electric Corporation, "Performance Leadership Through Total Quality," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Ficken, Todd E., Martin Marietta Astronautics Group, Inc., "Inputs to Trade Studies and Total Quality Management," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 242-245.

The success of U.S. industries has been exemplary, but in order to carry that image of greatness into the upcoming century, our ways of doing business need to change. One area to address with this change is the methods implemented in performing trade studies for the purpose of product development. In order to achieve a quality product, methods for performing multi-parameter trade studies need to be developed . In addition, the issue of how to integrate the numerous inputs pertinent for multi-parameter trade studies while maintaining the credibility of the trade study results needs to be addressed.

Fickler, Stuart I., Systems Research Laboratories, Inc., "The Language of TQM," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 246-255.

Most references on TQM refer to the need to establish a Culture of Quality. A culture essentially rests on the underlying messages that are exchanged and accepted by the cultural membership. From this perspective, the successful establishment of TQM within an organization may be viewed as a problem in neurolinguistic communication. This paper addresses these neurolinguistic issues as they impact on cross-cultural and intracultural issues. The former examines the translation of the successful application of TQM by the Japanese to an American environment. It specifically addresses those issues in which a direct translation of Japanese methods could fail in an American cultural environment. It also examines TQM in an environment of Japanese management and American labor. With regard to the intracultural issues, it examines the appropriate messages that must be presented at various corporate levels in order to ensure effective dissemination of a Culture of Quality. Through this process, it reveals the common linchpin that permits the translation of TQM into a successful tool for American management. Specific communication strategies are suggested.

Fitzgerald, R.L., Techmatics, Inc., "Implementation of a Total Quality Management Program in Private Industry," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 256-265.

Requirements for successful TQM implementation:

- The success of a TQM program depends upon the demonstrated commitment of the highest level of management. This commitment must be shared by everyone who participates in the program.
- TQM implementation must be thoroughly planned and prepared for.
- TQM must be measurable.
- Employees must be given defined, quantified and measurable specifications, which are based on customer requirements, in order to correctly perform their jobs.
- Most employees want to do their jobs well. Management must provide them with the proper knowledge and tools, must be willing to listen to

> and act upon their ideas and suggestions, and must provide acknowledgement and recognition.
>
> The success of a TQM program will depend upon the amount of effort that everyone involved is willing to put forth. Implementation and continued participation are hard work, but the results can truly be outstanding.

Flint, Steven J., "The Malcolm Baldrige National Quality Award: A Strategy for World-Class Performance," *Reliability Analysis Center (RAC) Newsletter*, DoD Information Analysis Center operated by IIT Research Institute, Rome, NY, April 1990.

Foran, Michael, Assistant to the Commander for Quality, AGMC/QP, Newark AFB, OH, "An Early Application of Total Quality Management Within the Air Force Logistics Command," *Reliability Analysis Center (RAC) Newsletter*, DoD Information Analysis Center operated by IIT Research Institute, Rome, NY, June 1989.

Fortuna, Ronald M., "Beyond Quality: Taking SPC Upstream," *Quality Progress*, June 1988, pp. 23-28.

Fuller, Tim, "Achieving the Corporate Vision Through Policy Deployment-Cornerstone of TQM," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Gartman, Col. Jerald B., USMC, and John S.W. Fargher, Jr., Naval Aviation Depot, Cherry Point, NC, "Managing the TQM Cultural Change," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 142-147.

> Continuous quality and productivity improvement, strategic planning objectives, enfranchising the artisan to manage his own work, rewards as incentives, and ultimately changing the corporate culture, although requiring the leadership of top management, requires implementation at the lower levels of management. The ability of these managers to transition to new styles of participative management and their commitment and support for change must be considered and incorporated into the change process. The employee involvement process *must* include these managers. Organizations must better equip first-line and mid-level managers to function successfully in their new roles. Middle management must learn to cope with increased spans of control, use new technology such as CIMS, and rely upon a participative management style for solutions. These first-line and mid-level managers are in a position to grasp the production of a particular product or service, a perspective that is often lost by upper-level managers as they are concerned with the business environment. In the day-to-day decisions made by the first-line and mid-level managers, they are often in the best position to make the changes necessary to alter the processes and eventually the culture.

Gartner, William B. (Georgetown University) and M. James Naughton (Expert-Knowledge Systems, Inc., "The Deming Theory of Management," *The Academy of Management Review*, Volume 13, Number 1, January 1988, pp. 138-142.

General Motors Corporation, *Highlights of Total Quality Management Philosophies and Applications*, Second Edition, 1990.

> Total Quality Management (TQM) is a term without a universally accepted definition. For our purposes, we have defined TQM as a system which is concerned with management approaches to improvement of all products and services, processes and systems. Further, these approaches must support

the consistent management of these things after improvement has been made.

It has been written that "If Total Quality Management is to be successful, it must be seen as a long term strategy which brings about fundamental changes in organizations, their values, cultures, structures, policies, processes, practices and procedures. The strategy for change is multidimensional, the process is incremental, and the goal is continuous improvement."

This booklet provides highlights of TQM approaches. The success elements described herein are essential ingredients for the development of a TQM process and are offered as a consensus view of leading quality proponents and practitioners. Specifically, successful processes are those that create and maintain an organizational culture which promotes and practices continual improvement of quality.

In preparing this overview, the approach has been to consider lessons learned from both philosopher and practitioner and to provide a brief review of the key points contained in various quality management systems.

Geoffrey, Steven, Ford Motor Company, "Continuous Improvement," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Gilks, John F., A.T. Kearney, Management Consultants in Toronto, "Total Quality: Wave of the Future," *Canadian Business Review*, Spring 1990, pp. 17-20.

Although its full impact is not yet being felt, total quality (TQ) has become essential to success in some manufacturing-intensive industries. Ford Motor Co. of Canada Ltd. has changed conventional thinking in every area of manufacturing, engineering, and design. As a result, Ford has stabilized its position in the automobile market and restored profitability. The experiences of other manufacturing-based industries have been similar. Research findings conclude that, in any business, there are several basic types of business processes, each demanding a different emphasis in the way TQ is applied. The *waves* of TQ are: (1) Engineered quality, which is applied to the product itself; (2) Repetitive service quality, which concentrates on the service delivery; and (3) The application of TQ principles that have a unique output, such as advertising development, consulting studies, and legal briefs. At this stage, the existence of a fourth wave of TQ is pure speculation. It ought to be possible to apply TQ to decision processes surrounding strategic asset deployment.

GOAL/QPC, *The Memory Jogger, a Pocket Guide of Tools for Continuous Improvement*, Second Edition, Methuen, MA, 1988.

Gold, Lois, Hewlett-Packard, "Implementing Hoshin and Daily Management in an Area Sales Module," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Hoshin is the business planning process utilized by all the Areas in the Eastern Sales Region of Hewlett-Packard The case study looks at an organization which has implemented the Hoshin planning process in its Sales, Support, and Administrative Organizations. The presentation focuses on the elements and how it was implemented, specifically in the New York Area--problems encountered and successes.

Among other things, the discussion looks at problems encountered in applying the *theoretical Hoshin* process to a matrix organization (multiple reporting relationships). It will look at some practical approaches to making these concepts *usable* by all levels of the organization--where to compromise on the theory and mechanics, where to hold firm.

The final part of the presentation discusses *daily management*--the management of your key processes. This was the missing piece of the puzzle in order to successfully implement Hoshin *breakthroughs*.

Goldschmied, Fabio R. and Nicholas V. Petrou, "Total Quality Management Within Multilevel Multigoal Hierarchical Systems: A Conceptual Introduction," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 266-280.

Total quality management, comprising engineering, design, manufacturing and maintenance, emphasizes organizational structure while viewing the participants as motivated goal-seeking units and it recognizes explicitly that the organization always comprises interconnections of subsystems, with both multiple levels and multiple goals.

Hierarchical structures provide better quality management, adapt faster to environmental changes, and similarly prevent the ready propagation throughout the system of a catastrophic unit failure. With the ultimate objective of designing adaptive organizational structures which would be optimal for total quality management and thus for survival in the swiftly changing world with finite resources, it appears that the rapid development of the theory of multilevel multigoal hierarchical systems offers the best hope today. Such theory must cut across the current classical, behavioral and systems-oriented approaches, i.e., it must comprise valid elements from all three.

The problem is to define quality for engineering, design, manufacturing and maintenance in terms of the language of each organizational level and to set quality goals for each level.

The theory is well adapted to the study of large social and political organizations where the higher unit may know the optimal solution yet it cannot impose its execution; rather it has to establish the relationship between the lower units so that they themselves arrive at such optimal solution. This is the key problem of total quality management within a complex organization.

Grunenwald, William J., ADM Consultants, Inc., "Implementation: The Real Total Quality Challenge," *Proceedings of the IEEE 1989 National Aerospace and Electronics Conference, NAECON 1989*, Volume 4, pp. 1471-1474.

Seven steps to total-quality implementation are listed and discussed. These are: (1) Establish a full-time advocate; (2) Develop a formal plan; (3) Be consistent; (4) Provide the resources; (5) Select improvement areas carefully; (6) Consider outside help; and (7) Be patient.

Gunter, Bert, "The Use and Abuse of C_{pk}, Part 4," Statistics Corner, *Quality Progress*, July 1989, page 86.

Hamson, Ned, Fred Jenny, and Michael Elliott, Unisys Defense Systems, "Total Quality Commitment . . . Unisys Defense Systems," *Journal for Quality and Participation*, December 1989, pp. 6-15.

Unisys Defense Systems' executives decided that making a commitment to quality was the only way to do business in a highly competitive and ever-

changing defense and world marketplace. This commitment is being met through the organization's strategic defense plan, which embodies total quality management principles and involves management in all business processes. Ethics training for employees emphasizes the tie in between quality and ethics. Quality objectives are being put in the performance plans of everyone, and Unisys management is making sure that employees understand that meeting those objectives is a condition of employment at Unisys. At the same time, outstanding performance is being recognized and rewarded. This quality commitment is process-oriented, in that it attempts to achieve a mindset for a continual process improvement. Another characteristic of this program is that it is top-down driven. The customer benefits, the company benefits, and the employees benefit. This quality commitment effort is truly a win-win opportunity for everyone at Unisys.

Harmer, Chet, Hewlett Packard, "Service TQM," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Harmon, L. Kenneth Jr., Virginia Productivity Center, "Total Quality and the Management of Performance Improvement," *SAM Advanced Management Journal*, Autumn 1988, pp. 4-12.

A major breakthrough in the evolution of professional management may be underway, in response to the need for performance improvement. A new management discipline will likely emerge that is a self-enhancing process for the participative management of continuous improvements in total business performance. To compete, survive, and prosper in the future, an organization will have to excel in the continuous improvement of its total business performance, which includes quality, productivity, and quality of working life. All organizations will perceive themselves as having customers, revenue, operating costs, and the opportunity to both excel in customer service and generate a financial surplus. The following phases of management activity comprise employee efforts in this approach: (1) Identification of performance problems and opportunities; (2) Planning for the implementation of operational changes; (3) Implementing the desired changes; (4) Monitoring effort and results; and (5) Reinforcing contributors at both the individual and team or group level.

Harrington, H. James, *A Guideline to Improvement*, Harrington, Hurd and Rieker, Los Gatos, CA, pp. 120-127.

This paper provides an outline of a proven, effective improvement process. This improvement process is the result of a detailed study the author conducted of the improvement activities in over 60 U.S. companies. If implemented properly, the improvement process is an effective way of bringing about positive changes in a company.

Harrington, Steve, "Process Management: A TQM Approach for Middle Managers," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 127-135.

Harrington, Hugh J. and Jack B. Revelle, Hughes Aircraft Company, "Hughes Aircraft Manages Total Quality Control in a DoD Environment," *Industrial Engineering*, December 1989, pp. 16-21.

The Department of Defense (DoD) has an obligation to both taxpayers and U.S. military service personnel to provide affordable and high-quality products. The DoD does this by exercising control over defense contractors from a product's conception to its production. At Hughes Aircraft

Company, one of the top ten contractors in terms of DoD awards, two programs have been employed for several decades: the Cost Improvement Program (CIP) and the Performance Improvement Program (PIP). These programs have several basic guidelines for implementation: (1) The desire to learn from experience in order to achieve quality; (2) The encouragement of a participative management for effective problem solving and decision making; and (3) The establishment of organizational goals through which quality can be attained. As a result of their efforts, Hughes intends to produce the highest quality products in the industry.

Harris, Marilyn and Christa L. Walck, "Managing a Megasystem Transformation in the Ford Motor Company: A Retrospective Retrieval of the Progress of Cultural Change," *Consultation*, Volume 7, Number 2, Summer 1988, pp. 67-85.

Teams of external and internal change consultants have guided an eight-year cultural change effort which has had a powerful impact on the way the Ford Motor Company now runs its business. A description is offered of the means by which the efforts of a few professionals were leveraged to provide consulting to a very large and complex global organization, a megasystem in change. The desired outcomes were brought about through managing a transformational cycle of learning that led to empowerment and diffusion--a cycle in which the organization moved from one that was intervening through "training for simplicity" to one that is "educating for complexity" and developing its employees for the complex realties of today and the future.

Harvey, David, "TQM--A Revolution Spurned," *Manufacturing Processes*, December 1989.

Harry, Mikel J., "The Nature of Six Sigma Quality," Motorola, Inc., Government Electronics Group.

This booklet highlights the six sigma product quality concept and its relationships to Motorola's position in the marketplace.

The discussion zeros in on the concept of six sigma, which advocates that there are strong relationships between product nonconformities or *defects* and product yield, reliability, cycle time, inventory, schedule, and so on. As the number of defects found during manufacture increases, the number of sigmas decreases. In other words, the larger the sigma value, the better the product quality--and vice versa. Although the ultimate aspiration is zero defects, the threshold of excellence is six sigma quality.

Interestingly, six sigma quality is estimated assuming *typical* shifts and drifts in the average. In this sense, 99.99966 percent capability at the *part* and *process step* levels is an intermediate target toward the ideal of perfection. This may be illustrated by considering a product that contains 300 parts and the related manufacturing process that consists of say, 500 individual steps. A six sigma capability at the part and process step levels would ensure a final *rolled throughput* yield of 99.73 percent. This would be to say, out of every 10,000 units of product manufactured, there would be 9973 units that would be produced completely free of nonconformities. Of course, this example assumes that each part and process step possesses only one opportunity for nonconformance, that all parts and steps are independent, and that nonconformities are randomly distributed.

The notion of variation is presented as the number one enemy of quality, yields, and costs. It must be arrested and ultimately eliminated in order to

achieve *best in class*. By attacking variation during the design phase, within suppliers' processes, and within our own processes, six sigma product quality can be achieved. In doing so, the foundation of excellence is laid.

The discussion also focuses on a more statistically based understanding of the six sigma program. It describes the arithmetic mean (μ), standard deviation σ and practical uses of the normal distribution. In particular, the rationale for making quality and yield estimates under the assumption of a 1.5 σ shift in the mean is emphasized. Based on the statistical perspective, the product and process engineering viewpoints are brought into focus by means of analytical examples. Through the discussion and examples, insights are developed as to the objectives of the six sigma program: enhanced product quality, yield, and cost--all of which, in turn, improve customer satisfaction.

Hill, J. Douglas, Member IEEE and John N. Warfield, Senior Member IEEE, "Unified Program Planning," *IEEE Transactions on Systems, Man, and Cybernetics*, Volume SMC-2, Number 5, November 1972, pp. 610-621.

Program planning begins with problem definition and ends with planning for action. The key products that result from the problem definition, value system design, and system synthesis steps are discussed and interrelated through the use of interaction matrices. Particular emphasis is given to defining objectives and to defining a set of measures on the objectives by which to determine their attainment. Interaction matrices relate objectives measures to objectives and link activities and measures of their accomplishment to the attainment of objectives. A major consequence of program planning is the choice of a program to pursue, and identification of the projects that will be carried out as a part of a selected program. Selecting the set of projects is discussed in terms of consistency with corporate or agency policy, and the economics, risk, and potential benefits associated with each project. A criterion function that incorporates the latter three factors is described and proposed as a practical way of evaluating the relative merits of projects.

Hillkirk, John, "Top Quality is Behind Comeback, *USA Today*, 28 March 1989.

Holpp, Lawrence, Development Dimensions International, "Ten Reasons Why Total Quality Is Less Than Total," *Training*, October 1989, pp. 93-103.

The concept of total quality improvement (TQI) demands that an organization be redesigned to keep it responsive to customers' needs as the product goes from one department to another. Some of the problems commonly encountered in a TQI effort include: (1) Unrealistic vision statements; (2) Performance objectives that have been turned into limited, quantifiable goals; (3) Executives who use the quality issue to gain personal power; (4) Work teams and supervisors who are passed by in the momentum of quality improvement; (5) Nonstatistical thinking; (6) New-program burnout; (7) Inadequate training; (8) People driven apart by some failure of support, training, or clear goals; (9) An inactive role by senior management in the TQI effort; and (10) Resistance to change.

House Republican Research Committee, Task Force on High Technology and Competitiveness, *Quality as a Means to Improving our Nation's Competitiveness*, 12 July 1988.

Houston, A. and S.L. Dockstader, "A Total Quality Management Process Improvement Model," *Navy Personnel Research and Development Center*, NPRDC TR 89-3, December 1988.

The use of TQM principles and the Plan-Do-Check-Act cycle in Navy industrial organizations requires the adoption of managerial practices and responsibilities that managers have little, if any, experience in applying.

This report has been written to serve as a bridge between theory and practice. Specifically this report has three objectives: (1) to define the steps of the process improvement model by describing specific activities associated with each step; (2) to describe roles and responsibilities of managers and others in relation to the model; and (3) to give a brief overview of basic statistical process control methods.

Huang, Maria and John D. Kotlanger, FMC Corporation, "Barriers to Performance Measurement Within the White Collar Environment," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 185-191.

Organizations implementing process performance measurement within the white collar workforce can significantly improve their chances for success by focusing their attention in four areas:

1. Stressing that measurement is the tool of the employee for controlling their process rather than a management tool for reporting or appraising individual performance.
2. Recognizing that implementation of performance measures will occur at different rates based on the complexity of the organizational issues encountered.
3. Recognizing that products and subproducts contracted for by the Department of Defense must be clearly understood and integrated into the total program process to be value-adding.
4. Organizational reward systems must be adjusted to reward team performance rather than individual performance.

Hubka, V., ETH, Zurich, Switzerland, "Design for Quality," *Proceedings of the International Conference on Engineering Design, ICED '89*, pp. 1321-1333.

The term "quality" is discussed. Factors that influence the quality of a product during the design process are derived from the general model of the design process. These factors are explained in more detail. Design quality is contrasted to the concerns of ISO 9000 series, which relate more to production and management.

Huthwaite, Bart, "Design for TQM," *Institute for Competitive Design (ICD)*, Rochester, MI, June/July 1989.

Huthwaite, Bart, "Design for TQM, Alphabet Soup," *Institute for Competitive Design (ICD)*, Rochester, MI.

Johnson, Capt. Bruce A., Office of Special Assistant for R&M, SAF/AQ and DCS/L&ER, "Findings from R&M 2000 Variability Reduction Process Trip to Japan (10-14 October 1988)," DoD Letter, dated 18 November 1988.

Johnson, Cynthia Reedy, Colorado Division of Youth Services, "An Outline for Team Building," *Training*, January 1986, pp. 48-52.

Kammert, Sandra L., Martin Marietta Manned Space Systems, "Maintainability: A Critical Link in TQM," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 148-151.

> Maintainability has received recent notoriety in SRM&QA, but still is often the last engineering aspect of a design included, and the first deleted, during a program. This is unfortunate since maintainability is the area of lifetime product support having the greatest potential for substantial cost savings in terms of manpower, supply support, and technical documentation. The *quality* of maintainability must be emphasized as is the quality of the design. TQM, as an initiative for performance and product improvement, incorporates the principles and tools of Concurrent Engineering. This is an emphasis long awaited by those working to produce a high quality as well as an easily maintained product.
>
> The one overall conclusion relative to the area of maintainability in relation to TQM is that there is a critical link. While each situation--be it commercial or governmental in nature--is unique, the common thread of ease and economy of maintenance must not be overlooked or ignored. No one has unlimited resources for support. The designers must optimize the final product so the users can get what they have paid for--a product that works when it should, and is easy to maintain when it fails.

Kano, Noriaki, Science University of Tokyo, "TQC Master Plan," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Kano, Noriaki, Science University of Tokyo, "TQC in Japan and the U.S.," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Kano, Noriaki, Science University of Tokyo, "Overview, QC Circles in Japan," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

King, Robert, "Listening to the Voice of the Customer: Using the Quality Function Deployment System," Focus/Quality Management, *National Productivity Review*, Summer 1987, pp. 277-281.

> In many of the cases reported, the use of quality deployment has cut in half the problems at the beginning (design) stages, shortened development time from one-half to one-third, all the while assuring users' satisfaction and increasing sales. However, if it is applied incorrectly, it could increase work without producing any good.

King, Bob, GOAL/QPC, "Visuals From Models for Developing a TQM Master Plan for Your Company/Organization," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Krakov, William, Total Quality Management, Viewgraphs, 1988.

Leach, Kenneth E., Glove Metallurgical Inc., "The Evolution of Quality at Globe Metallurgical," *Proceedings of the GOAL/QPC 6th Annual Conference*, MA, 4-6 December 1989.

Locander, William B., The University of Tennessee, Knoxville, "Brokering Marketing into Total Quality," *Survey of Business*, Summer 1989, pp. 31-35.

> In the future, companies working under world-class quality and productivity standards will have to include the marketing function as the firm's eyes and ears to the marketplace. The establishment of a *customer empathy* perspective is critical to being a market-driven company. Measurement is an important part of a quality management system.

Systems indicators, such as dollar sales, are global measures of how the system is operating. Some suggestions to help managers understand consumer needs are: (1) Managers must establish a posture of studying the market on a periodic basis; (2) Managers should not only rely on field studies, but should deal with customers themselves; and (3) Managers should go to the distribution channel and tap the staff's years of experience with the customer. Balancing trade and consumer needs with the capability of production and logistics function is essential to customer-driven management.

Maddaloni, Angelo and Wally Cervantez, Bridgestone, USA, Inc., "Bridgestone/Firestone Participation Systems," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Maxon, Capt. Bruce E., SC, USN, *CEO's Role in Achieving Productivity Through Quality*.

Mansir, Brian E. and Nicholas R. Schacht, *An Introduction to the Continuous Improvement Process: Principles and Practices*, Logistics Management Institute, Bethesda, MD, July 1989.

The Continuous Improvement Process (CIP) is a means by which an organization creates and sustains a culture of continuous improvement. The organization deliberately seeks to create a positive and dynamic working environment, foster teamwork, apply quantitative methods and analytical techniques, and tap the creativity and ingenuity of all its people. Collective effort is focused to better understand and meet internal and external customer needs and to continuously increase customer satisfaction. Employing CIP in an organization can substantially improve the quality of its services or products, increase productivity, and reduce costs across a broad spectrum of systems, products, and services.

A few of the major companies that now use and proclaim their commitment to CIP-related management technologies are Phillips, Ford, Xerox, IBM, Hewlett-Packard, Toyota, Honda, Boeing, Chrysler, and Texas Instruments. In the public sector, DoD has instituted a continuous improvement initiative called Total Quality Management. These and other organizations that are committed to a continuous improvement philosophy report substantial improvement in quality, productivity, throughput, and employee morale, with significant reductions in cost, errors, leadtimes, waste, and customer complaints. The consensus among CIP-oriented companies is that these technologies are the key to their long-term competitiveness and survival.

McArthur, Daniel and David Carr, Coopers and Lybrand, "Implementing TQM and JIT in a Manufacturing Environment," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 175-180.

TQM can and should be used in conjunction with other improvement programs. At a large manufacturing facility, TQM was used as the quality component of a Just-in-Time (JIT) cycle time management system. TQM was also introduced to non-production staff and to vendors, resulting in efficiencies and subsequent reduction cost of quality. Use of a single quality method throughout an organization avoids confusion and increases the power of all other productivity and efficiency improvement programs.

McMakin, Grover, USAA Insurance, "USAA's Mission and How it is Supported by a Quality Management Program," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Mendelssohn, Alan S, Joseph C. Ferrel (Florida Power and Light Co.), and Robert E. Bartz, Qualtec, Inc., "Simplified Project Management, The Key to a Quality Project," Project Management Institute, Seminar/Symposium, San Francisco, CA, 17-21 September 1988, pp. 655-661.

> Simplified Project Management is the concept of satisfying all the customers on the project, both internal to the project team, as well as external to it. This philosophy of customer satisfaction uses an approach that is both simple and basic. It is simple in that it does not involve any complex theories or implementation processes. It only requires the identification of the project's customers, what their needs are, and how those needs can be satisfied. It is basic in that it uses the same organizational structure, people and tools that are currently on the project and combines them with some additional tools and approaches to achieve the goal of a totally successful project.

Meyland, Dr. Robert F., Martin Marietta Electronic Systems, "Total Quality Management (TQM) Key Concepts and Implementation Methodology for Defense and Aerospace Industries," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 322-326.

> The responsibility for TQM is assigned equally to the Mission-Area Vice President/Program Directors and to the Functional Vice President/Directors reporting to the President. The President's staff comprises the Quality Steering Committee which provides guidance and TQM policy for continually improving the quality of company products. TQM requires involvement by all employees at all levels of the organization. TQM is an integral part of every functional activity in the organization including the formation of continuous process improvement teams made up of personnel who normally work in these areas. In addition to improvement teams identified as Performance Management Teams (PMTs), concurrent engineering tasks/team activities evolve during development to assure all product "ilities" (e.g., producibility, reliability, supportability, maintainability) are integrated into the product design. Statistical process control techniques and automation have been integrated into the production process, together with supplier TQM to increase product/process robustness. Various media/awards have been established to communicate and recognize individual improvement accomplishments. In addition, a reward program (e.g., Ideas Count) has been established to share improvement savings with the idea originator. These actions will ultimately lead to attainment of a customer certified-producer status for quality products.

Miller, Lawrence M., The Miller Consulting Group, "Creating...TQM," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Mishne, Patricia P., Associate Editor, "A New Attitude Toward Quality," *Manufacturing Engineering*, October 1988, pp. 50-53.

> Managing for quality means nothing less than a sweeping overhaul in corporate culture and a radical shift in management philosophy.

Mogilensky, Judah, Contel Federal Systems, "Applying TQM to Software Development: Process Enhancement Program," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 98-104.

Contel Federal systems has initiated the Process Enhancement Program (PEP) as a vehicle for applying the concepts and principles of TQM to software development. The PEP encompasses four Task Areas. The Policies, Procedures, and Standards area works towards the development of formal, written guidance for the development process. The Tools and Environment area works towards the development of an Integrated Programming Support Environment (IPSE). The Education and Training area provides for the training of individual developers in the use of the Procedures, the IPSE, and the languages and methodologies underlying them. The Measurement and Estimation area includes the collection of process metrics, both to permit measurement of productivity and quality progress, and to provide direction for the continuous improvement of the development process. Joint, integrated progress in all of these areas is seen as the key to success. Contel has already begun to apply PEP products and approaches to a Government contract software development program, the BIDDS Management Subsystem. Initial indications are that these approaches can be effectively applied to real projects.

Morooka, Koji, Tokai University, "Hospital Service Quality and Productivity," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Motley, William T., *Total Quality Management*, Office of the Director for Industrial Productivity and Quality, OASD (P&L) TQM, February 1989.

The purpose and scope of this paper are:

- Outline the basic principles of Total Quality Management
- Summarize the requirement for the successful implementation of TQM.

Murphy, Donald H.K., Hughes Aircraft Company, "Company Wide Strategic Planning Using the 7-M Tools," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Murphy, Donald H.K., Hughes Aircraft Company, "Continuous Improvement," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, Viewgraphs, 4-6 December 1989.

Muse, Karen and Mark Finster, University of Wisconsin, "Suggestion Systems," Proceedings of the GOAL/QPC 6th Annual Conference, Boston, MA, 4-6 December 1989.

Quality and productivity improvement has been a topic of endless discussion in the business world in recent years. Japanese industry now sets the standards by which the rest of the industrialized world judges itself. Indeed, other nations often find themselves falling far short of Japanese standards of excellence, and look for quick and easy answers to address their shortcomings. The Japanese in the postwar years have taken many quality concepts which originated in the west, and improved and implemented them.

One such quality concept which originated was employee suggestion systems or plans. The Japanese have taken this concept and expanded it far beyond its humble beginnings in the *suggestion box*. Most large Japanese firms and about half of the small and medium sized firms have employee suggestion systems. There are an estimated 4,000 employee suggestion plans in firms in the U.S., but few compare in scale, nor depth, to typical Japanese systems.

This paper is organized fairly simply. First is a discussion of the evolution and process of suggestion systems in the U.S., with mention of focus, problems, and trends. A similar section follows describing Japan. Finally, a comparison is drawn of some of the key features of the systems of the two countries, and how or if suggestion systems complement other quality programs, with specific company examples. A plan of action for improving suggestion systems summarizes the ideas presented.

National Institute of Standards and Technology, "1990 Application Guidelines," Malcolm Baldrige National Quality Award, Gaithersburg, MD.

National Center for Manufacturing Sciences, "It's Time to Reexamine the Importance of Quality," *FOCUS Newsletter*, Volume 3, No. 4, April 1990.

NAVAIR Viewgraphs, Concurrent Engineering Task Force Meeting, 25 September 1989.

Navy Manufacturing Technology Program Report, *Building Quality Into the Process*, November 1988.

Newhouse, R.W., General Dynamics, "What Can We Do After We've Done It All?," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denv--, CO, 1-3 November 1989, pp. 123-125.

Noble, Cheryl and Kevin O'Donnell, Florida Power and Light Company, "Building a Quality Improvement Program at Florida Power and Light," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

One of the great things about quality is that you don't have to sell it to your customers. All you have to do is produce it; the rest takes care of itself.

Norausky, Patrick H., Aerojet Ordnance Downey, "TQM: A System Success Story," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 152-157.

Customer satisfaction and continuous improvement form the basis of the Department of Defense TQM initiative. This initiative recognizes that a thrust is needed to better inculcate the quality process throughout a company. It requires the difficult task of changing the culture of not only a company, but also suppliers used by a company.

An excellent example of a TQM system success story is found at Aerojet Ordnance. As a defense contractor, Aerojet Ordnance, an operating unit of GenCorp Aerojet, is engaged in the design, development and production of munition systems, ammunition and heavy metal products. Five years ago, Aerojet Ordnance realized that a change in the quality approach that had already resulted in an excellent quality record would be necessary to remain competitive, be profitable, and to grow. A quality system called Big "Q" was devised. It turns out that this system mirrors the spirit and content of DoD's TQM initiative. In fact, regardless of what the system is called, it represents the vision, principles, and structure of a total quality approach that must be realized, regardless of the DoD initiative, in order for any business operation to be competitive, profitable and to grow. The U.S. Army Armament, Munitions and Chemical Command recognized this outstanding TQM system by honoring Aerojet Ordnance with certification under the Contractor Performance Certification Program (CP).

This paper examines Aerojet Ordnance's TQM system involving (1) process of initiation, (2) cultural change within Aerojet Ordnance and its suppliers, (3) sustaining approach, (4) operational tools (i.e., Statistical Process Control (SPC), Quality Function Deployment (QFD), and Taguchi), and (5) results. Recommendations are covered relative to lessons learned.

Osborne, Guy A., Universal Foods Corporation, "Quality the Universal Way," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Parker, John, Martin Marietta Astronautics Group, "Peacekeeper IFSS - A TQM Success Story," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 158-166.

This paper is written by the project director of a $1200 million hardware production contract. It is a case study that describes how the contract that he manages went from a projected $19 million overrun to a $33 million underrun. It shows, with examples from the project history, how quality, cost and schedule performance were improved through the implementation of a Total Quality Management program. The paper discusses how high-performance teams were formed at each level of the organization as a vehicle for empowerment and how this increased employee involvement is the foundation for continuously improved performance. It is shown that as performance improvement initiatives reach fruition in an empowered environment they provide leverage for even greater accomplishments.

"The Payoff From Teamwork," *Business Week*, 10 July 1989, pp. 56-62.

"Pentagon's TQM Chief: 'Not my Job' to Enforce Quality," *Aerospace Daily*, 25 May 1990, p. 329.

Phillips, Ronald T., "An Approach to Software Causal Analysis and Defect Extinction," *GLOBECOM '86: IEEE Global Telecommunications Conference Proceedings*, pp. 412-416, 1986.

This paper briefly reviews the history of quality circles and discusses the experience of an implementation of a quality improvement team or quality circle in the software product development environment at IBM Corporation and its use of the causal analysis concept. The implemented team concept could apply to software in general as well as to communications software. The concept of the software quality team and its implemented organization is described in detail. Responsibilities of team members and management are also discussed.

The quality team allows for the extinction of errors as well as better methods of detection and prevention through causal analysis (1-2-3 process). The process of team operation and the process of defect prevention and extinction as implemented by the team is integrated within the software development process. The evolution of this implementation is reviewed from the point of view of how the quality team implementation integrates and addresses the requirement of up-to-date process documentation, the requirement for new defect prevention tools, and the requirement of process changes to prevent defects.

Highlighted in the paper are data experience and how causal analysis contributes advances in the form of several new tool implementations and process examples that can contribute significantly to continued quality improvement.

Piscatella, Michael J., Textron Lycoming Stratford Division, "Total Quality Management and The Transitioning Company: The Perfect Fit," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 136-141.

Textron Lycoming has set a course to bring the goodness of past successes and the new initiatives of the future under the Total Quality Management umbrella. This paper will discuss the path that Textron Lycoming is taking to achieve a culture of continuous improvement. If you can measure an element, it can be improved upon. The objective is to get 6,500 participants aware of the elements, the customer viewpoint, and the measurement process. The philosophy of continuous improvement has become part of the culture.

Pratt, Robert N., Textron Defense Systems, "Total Quality Management and the Big "Q" Program at Textron Defense Systems," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 266-280.

Total Quality Management is a disciplined structure focused on continuously improving all the processes within an organization It combines fundamental management techniques and tools, and provides the means for measuring progress, implementing improvements, and assessing performance. The goal of Total Quality Management is to improve the quality of products and services while achieving reductions in the cost of operating a business. The objective of Total Quality Management is to enlarge the concept of quality, focusing on the total system earlier in the process, starting with the customer requirements. Under the Total Quality Management strategy, a new cultural change from nonconformance correction to nonconformance prevention; from quality inspected into products to quality designed and fabricated into the process and hardware; from emphasis on cost and schedule to emphasis on quality cost and schedule.

Total Quality Management applies to everyone and builds and sustains a culture committed to continuous improvement. Total Quality Management methodologies provides a systematic road map for accomplishing specific tasks such as design of experiments, statistical process control and many other key tools and techniques. Total Quality Management is an organized management philosophy requiring extensive time, skill and resources. The results of TQM can, therefore, only begin to be measured over the long run.

Ponce de Leon, Ralph, Motorola, "The Integration of TQM and Motorola's Six Sigma Initiatives," presented at the Conference on Concurrent Engineering: A Practictioner's Look at Industry and Government Initiatives, sponsored by the Society of Manufacturing Engineerings, Washington, DC Chapter and the Concurrent Engineering Research Center, 3 October 1990.

"The Push for Quality," Special Report, *Business Week*, June 8, 1987, pp. 130-144.

The President's Productivity Improvement Program, Office of Management and Budget, "Quality Improvement Prototype," Naval Aviation Depot, Cherry Point, North Carolina, Department of the Navy.

Rhea, John, "Total Quality Management: Myths and Realities," *National Defense*, January 1990, page 25; *Current News Special Edition No. 1838*, March 1990, page 24.

Ropelewski, Robert R., "Wave of Quality Initiatives Sweeps Over DoD, Industry," *Armed Forces Journal International*, January 1990, page 54; *Current News Special Edition No. 1838*, March 1990, page 9.

Sansom, R.E., TRW, "The Changing Role of Quality Assurance Under TQM," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 121-122.

> Dr. Edwards Deming's third point in his fourteen point set of TQM principles states:
>
> "Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place."
>
> No doubt many of us have expressed a similar sentiment--*build in quality the first time.* If we actually do manage to imbue our developers with this practice, to the point it is truly institutionalized, what could be the role of the classical "QA" folks? I believe that we must rethink how we go about typical QA activities in the broad context of aiming to deliver quality products. We must take into into consideration things like MIL-Q-9858A and explore alternative means to assure to our government customers that indeed those products meet the quality standards we embrace.

Scholtes, Peter and Heero Hacquebord, *A Practical Approach to Quality*, Joiner Associates, Inc., Madison, WI, 1987.

> When W. Edwards Deming describes an organization committed to quality, we get a compelling picture of what we should strive for and how we ought to be. But there are precious few instructions on how to begin such a transformation. This paper is an effort to fill some of that gap. What we propose here is a practical approach to becoming a quality organization. We call it practical because it is based on what we believe are some pragmatic realities of everyday business life: that change is very difficult; the resistance to change is frequently strong and persistent; that no matter how much a company might want to transform itself to some new order, it must continue doing business, and for the time being, do so in the way it knows best. Transformation, therefore, involves a sort of adolescence: a period of inelegance when we shift from one way of being to a new way of being. We also call these approaches practical because they work. Contained here are things we have learned from decades of helping many and diverse organizations grow and improve.

Selby, Vernon. B., Space Launch Systems Co., "Total Quality Management (TQM)," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 373-378.

> TQM is total customer satisfaction, it is total commitment and involvement of all members of the organization. TQM must start at the womb (initial concept stage), and involve all phases and activities as well as most important, all people, to the tomb (final product, process or output).
>
> Quality of the process must be first and foremost at all of the various stages. Concurrent engineering must be developed and implemented to assure design and manufacturing producibility are considered simultaneously, which will ensure the satisfactory end result. Activities must be controlled by quality. Everyone must have quality instilled in their way of performing assigned tasks. Quality cannot be the last phase but, quality must be an

integral part of all processes. Every person must receive training in the quality way.

Each person must seek and accept self-improvement in all phases of their work life. W. Edward Deming's theory for management must be achieved: create a constancy of purpose toward improving product and service; cease dependence on inspection to achieve quality; and, above all, improve constantly and forever the system of production and service to improve productivity and reduce cost. TQM can help us achieve the status of WCM, World Class Manufacturer, without which we will not be competitive in the aerospace arena.

Shoji, Mikio, Kajima Corporation, Japan, "Without Muda, Muri, Mura," Mechanical Engineering, January 1988, page 41.

Shoop, Tom, "Can Quality be Total?," *Government Executive*, March 1990, page 20, *Current News Special Edition No. 1838*, March 1990, page 17.

Sinioris, Marie, Rush-Presbyterian-St. Luke's Medical Center, "Total Quality Management," Viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA, 4-6 December 1989.

Smith, D.G., Loughborough University of Technology, UK, "User Needs and Conceptual Thoroughness - the Genesis of New Products," *ICED '89 Proceedings*, Harrogate, UK, August 1989.

Todays highly competitive product environment has given rise to increased emphasis on creative techniques for the generation of new concepts. Experience has clearly shown that conceptual synthesis in a controlled manner must be preceded by an understanding of buyer and user needs and perceptions. These needs and perceptions encompassed in the product design specification, require conceptual exploitation to the full.

An approach to the generation of solutions incorporating team working is outlined.

If companies are to maintain leading positions in traditional products and also develop new areas, the creative potential of design teams must be developed to the full. The approach given, commencing with the identification of real needs, has been proven effective for a wide range of products and provides a method to assist in meeting the challenge of todays highly competitive product markets.

Smith, Bruce A., "Total Quality Management Will Require Procurement Changes, Perseverance," *Aviation Week and Space Technology*, December 1989, pp. 59-60.

The U.S. Department of Defense has been pushing the case for TQM with contractors. Management experts say that TQM concepts essentially remained on the shelf for many years because the U.S. economy was not challenged by offshore barrages until the 1970s. Implementation of TQM principles requires a dramatic change in the way that a business is run. The changes, which are permanent and pervasive, cut through traditional organizational structures and require long-term commitment from management. While quality measures can be applied in different ways, a common denominator is attitude--the attitude of each employee to continuously improve the product or service. Everyone in the organization becomes a problem solver above personal advancement, *turf wars*, authoritarian control, and short-term profit. With TQM as a permanent fixture, the continuous small improvements that are basic to the philosophy will add up to solid and significant achievement.

Strickland, Jack and Peter Angiola, "Total Quality Management in the Department of Defense," *1989 ASQC Quality Congress Transactions*, Toronto, pp. 806-810.

This paper explores some of the causes that have contributed to the current status of our economy, the stigma of poor quality associated with weapon systems, the adversarial relationship between Government and Industry and the general attitude of mistrust between management and labor. The paper addresses the new DoD approach to quality and offers a persuasive argument to the defense industry for joining in this revolution.

Strickland, Jack, "TQM, Linking Together People and Processes for Mission Excellence," Army Research, Development and Acquisition Bulletin, May-June 1989, pp. 9-12.

Strickland, Jack C., Director for Industrial Productivity and Quality, Office of the Assistant Secretary of Defense (P&L), "Key Ingredients to TQM," March/April, pp. 17-21.

Implementation strategy for this effort aims at achieving one broad, unending objective: continuous improvement of products and services across the breadth of the department's activities.

Strickland, Jack, "Total Quality Management, F-14 Program," Viewgraphs, September 1988.

Stuelpnagel, Thomas R., "Total Quality Management in Business--and Academia," *Business Forum*, Fall 1988/Winter 1989, pp. 4-9.

TQM is an improved management process that originated in the U.S. and was perfected in Japan. In a large measure, industry and government are making the change directly with the assistance of private and government training organizations. Universities should become aware of the revolution that is occurring in the TQM field, develop TQM master plans, and work toward developing study and curricula in support of TQM. This is achieved with a system designed to keep the customer continuously in the product cycle. Additional features of TQM include: (1) Using statistical methods to control both management and product processes; and (2) Making all processes in the management, product, and service chain subject to continuous improvement. TQM provides the opportunity for all employees within the organization to participate as team members, to help, to be heard, to be rewarded, and to excel.

Thomas, Robert W., Rome Air Development Center, "Total Quality Management-A Buzzword or Plan," *ISHM '89 Proceedings*, Baltimore, MD, pp. 55-58.

The U.S., faced with serious budget deficits in the 1980s, must now answer a major question for the 1990s--How to provide an adequate defense system that is both affordable and works when needed. The definition of adequate will be left to the technical strategists and the politicians. Developing an affordable defense system in which we have used advanced electronics to give us a parity with traditionally larger opposition forces has a great deal to do with the way we procure our electronic components. We now, for the first time in history, spend more maintaining field systems than we do in developing new systems. The reasons for this simple fact are complex and require individual analysis. One factor which is paramount in determining both the initial cost of the system and the cost to maintain the systems is quality of the electronic components which go into the system and how the quality of the components was achieved.

Tribus, Myron, American Quality and Productivity Institute, Hayward, CA, "Deming's Way," *Mechanical Engineering*, January 1988, pp. 26-30.

The Japanese revere the man who taught them that higher quality means lower cost. But in his own country, W. Edwards Deming has found few who will listen.

Volkema, R.J., George Washington University, "Problem Formulation in Planning and Design: What We Know and What We'd Like to Know," Planning and Design in Management of Business and Organizations, *1987 International Congress on Planning and Decision Theory*, Boston, MA, 17-20 August 1987, pp. 91-95.

This paper summarizes what we know (or think we know) about problem formulation in planning and design, and raises questions for future consideration.

Wagner, General Louis C., Jr., USA, Commanding, Headquarters, U.S. Army Materiel Command, "Army Materiel Command Posture on Total Quality Management (TQM)," Memorandum for Secretary of the Army and the Chief of Staff, Army, 28 November 1988.

Wagner, General Louis C., Jr., USA, "The Commander's Perspective," U.S. Army Materiel Command, January 1988.

Westinghouse Electronic Systems Group, ILSD Engineering 1990 Total Quality Plan and Training Materials, 11 April 1990.

Westinghouse Electronic Systems Group, ILSD, "Training Classes Heighten Total Quality Awareness," 2-page article.

Westinghouse Electronic Systems Group, ILSD, *Brassboard* Newsletter on Total Quality, Issue No. 60, May 1990, David H. Napolillo, Editor, Hunt Valley, MD.

Westinghouse Electronic Systems Group, *Total Quality Guide*, March 1990.

White, Bruce, Ford Motor Company, Canada, "How Quality Became Job #1 at Ford," *Canadian Business Review*, Spring 1990, pp. 24-27.

Ford Motor Company of Canada, Lt., adopted a policy of total quality (TQ) management that focused on enhancing product quality, increasing product innovation, and reducing costs in order to enhance its competitiveness. The implementation of TQ management included: establishing a statement of mission, values, and guiding principles; empowering group decision-making; and increasing employee training. The company's parent, Ford Motor Company, has identified a number of challenges for the 1990s, including producing the highest quality trucks and cars worldwide, becoming efficient on an international basis, and changing its corporate culture.

Whittaker, Barrie, AMP, Canada, "Increasing Market Share Through Marketing Excellence," *Canadian Business Review*, Spring 1990, pp. 35-37.

AMP of Canada, Ltd., developed the Quality Improvement Process (QIP) to improve customer satisfaction by enhancing the quality of its marketing organization. The implementation of QIP was based on developing a marketing quality improvement team that solicited customer feedback, identified major customer requirements, and created new measurement systems. Under QIP, AMP's marketing and selling functions were integrated, new customer-driven selling techniques were implemented, and

the marketing skills of employees were developed through new training programs. Quality is maintained by setting performance standards for all the jobs in the marketing organization.

Wilkinson, Harry E., University Affiliates, Inc. and James E. Spates, Action Counsel, Inc., "Why Don't More Companies Implement TQM -- SUCCESSFULLY!?," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 419-424.

A well-planned and implemented TQM program *can* achieve short, intermediate, and long-term maximum success when the cultural transformation process is well handled by top management and external facilitators.

- This includes addressing those factors which may lead to resistance, as well as those elements contributing to success.
- It requires significant involvement of the organization's top management as well as subordinate managers and employees in the identification of opportunities for cultural and subcultural transformations contributing to TQM program effectiveness.
- It requires their continued involvement in the planning and implementation of an integrated set of interventions in small increments over as long a period as is logistically reasonable that will still show steady TQM progress.
- It requires a never ending set of reinforcing activities.
- It requires top management investment in a significant career development program as part of the TQM program. (This also signals positive top management support to people throughout the organization.)

In this way, the organization preserves the strengths derived from individualism, competitiveness, and specialization while at the same time transforming the culture to emphasize cooperation, trust, a customer orientation, and a growing sense of comradeship as well. Thus, long term TQM success requires a high level effort to manage cultural transformations.

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DoD Quality and Productivity Month-January 1990, January/February 1990.

High Level DoD Support Shown for TQM, September 1989.

USD(A) on TQM, November 1989.

GOAL/QPC, *Competitive Times.*

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David Cook, "Total Quality Management--Fine Talk or Real Improvement?"
Yoshio Kondo, "Emphasis of Japanese Total Quality Management in the 1980s"
Henry R. Neave, "Deming '88, Part 1: Win-Win, Joy in Work, and Innovation"
D. Bertram, "The Future for Quality in Europe"
A.F. David, "The Customer/Supplier Relationship--the Nissan Way"
Ronald E. Blank, "Gaining Acceptance: The Effective Presentation of New Ideas"
N. Logothetis, "Managing the Component-Tolerances"
Paul Goodstadt, "Quality Service--The Corporate Holy Grail of the 1990s"
J.M. Asher, "Quantifying Quality in Service Industries"
A.F. Bissell, "Multi-Positional Process Evaluation: An Example and Some General Guidelines"
George Box and Stephen Jones, "An Investigation of the Method of Accumulation Analysis"
J.J. Dahlgaard, Gopal K. Kanji and K. Kristensen, "A Comparative Study of Quality Control Methods and Principles in Japan, Korea, and Denmark"
B. Sarkar, "Status of Quality control in Indian Industries--A Survey"
A.F. Bissell, "SPC in 'Non-Product' Applications"
Janit E. Buccella, "Auditing--A New View"

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ICED'89 Proceedings, Harrogate, UK, August 1989.

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Statistically Based Management, The ITT Research Institute Approach to Quality and Productivity Improvement, A Management Cultural Change Using Statistical Process Control, IIT Research Institute, Rome, NY.

U.S. Congress, OTA, *Making Things Better: Competing in Manufacturing*, OTA-ITE-443, Washington, DC: U.S. Government Printing Office, February 1990.

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Crosby, Philip B., *Quality is Free, The Art of Making Quality Certain*, McGraw-Hill Book Company, NY, 1979.

Eureka, William E. and Nancy E. Ryan, *The Customer-Driven Company, Managerial Perspectives on QFD*, ASI Press, Dearborn, MI, 1988.

Feigenbaum, A.V., *Total Quality Control*, McGraw-Hill Book Company, NY, 1983.

Goldratt, Eliyahu and Jeff Cox, *The Goal, A Process of Ongoing Improvement*, North River Press, Inc., Revised Edition, 1986.

Harrington, H.J., *The Improvement Process, How America's Leading Companies Improve Quality*, Quality Press, Milwaukee, WI, McGraw-Hill Book Company, NY, 1987.

Imai, Masaaki, *Kaizen, The Key to Japan's Competitive Success*, Random House Business Division, NY, 1986.

Juran, J.M., *Managerial Breakthrough, A New Concept of the Manager's Job*, McGraw-Hill Book Company, 1964.

Scherkenbach, William W., *The Deming Route to Quality and Productivity, Road Maps and Roadblocks*, CEEP Press Books, George Washington University, Washington, DC, 1988.

Schonberger, Richard J., *Japanese Manufacturing Techniques, Nine Hidden Lessons in Simplicity*, The Free press, a Division of Macmillan Publishing Co., Inc., NY, 1982.

Townsend, Patrick L. with Joan E. Gebhardt, *Commit to Quality*, A Wiley Press Book, John Wiley and Sons, Inc., NY, 1986.

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Matrix Product/Process Staff, Organization Review, 1990.

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Formulation of Integrated Product Teams, 1990

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Business Requirements and Management Issues, 16 January 1990

Alptekin, Sema, J. Kenneth Blundell, Winston Erevelles, Y.S. Dhanju, and K.M. Ragsdell, University of Missouri-Rolla, *Final Report on DFA/DFM Project for McDonnell Douglas*, No. 90DPC001, Draft, 6 February 1990.

Baglino, Mike, Teradyne, Inc., "Using ATE in the Design Process Shortens Product-Introduction Cycle," *EDN*, 5 April 1984, pp. 189-192.

> By integrating automatic test equipment into the design process at the prototype stage, you can maximize design-team effectiveness and simultaneously minimize product-introduction cycle times.

Bancroft, Carol E., IBM Corporation, "Design for Manufacturability: Half Speed Ahead," *Manufacturing Engineering*, September 1988.

> DFM techniques should be better defined to optimize the design of a product for its method of manufacture.

Berger, Joan, Otis Port, Mimi Bluestone, William Hampton, Zachary Schiller, and Karen Pennar, "The Push for Quality," *Business Week*, Special Report, June 8, 1987, pp. 131-144.

> To beat imports, the U.S. must improve its products. This means a whole new approach to manufacturing.

Bogard, Timothy V., Texas Instruments, "Integrating Systems Producibility into the Design Process," *Proceedings of the Second International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 April 1987.

> The task of integrating systems producibility concepts into any corporate environment is a complex challenge. It requires:
>
> - An understanding of what producibility truly is
> - A change in the engineering and management culture to provide a progressive environment for producibility concepts
>   - Development of detailed procedures, guidelines and new design methodologies

- Strategic planning to imbed producibility concepts into the next generation of design automation systems
- Feedback to the design/producibility/manufacturing community (measurement, ranking of yield, etc.)

Most of all, however, it requires commitment from all levels in the organization in a teamwork environment and the persistence to design it right the first time to ultimately succeed.

Box, George and Soren Bisgaard, University of Wisconsin-Madison, "Statistical Tools for Improving Designs," *Mechanical Engineering*, January 1988, pp. 32-40.

Statistically controlled experiments serve as a catalyst to design. These methods help engineers to build good quality into products, which should reduce the need to inspect bad quality out of them.

Bradley, Paul J., Martin Marietta, "Short-Term Benefits of Concurrent Engineering," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 41-45.

The bottom line for many companies and many managers is how quickly they get a return on their investment. When applying concurrent engineering techniques, one may need to wait a long time, for as one report pointed out, "Significant cultural and management changes underlie the successful implementation of concurrent engineering. As a consequence, considerable time (2-4 years) is often needed before benefits are realized from concurrent engineering."

However, while waiting to realize the long-term benefits, the manager can realize many short-term benefits from concurrent engineering.

Better Communication. Concurrent engineering provides an environment conducive to information exchange.

Higher Visibility. Items being worked by a team receive higher visibility because team members are constantly and consistently communicating information through the organization.

Enthusiastic Participation. The group dynamics generated by a concurrent engineering effort overflow into people and organizations not directly part of a team.

More Alternatives Considered. Multi-disciplined, energetic teams create more ideas than conventional methods.

Better Focus of Energies. Concurrent engineering lends itself to finding the best solution, the first time through. Ultimately, the energies of the company are focused on the right way sooner.

Other short term benefits may certainly exist. However, any healthy team, using concurrent engineering, will at least realize these five benefits.

Branan, Bill, Motorola, Inc., "Instilling a Design for Assembly Culture," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

The average product design group has little incentive, motivation, or training to design a product for efficient factory assembly. Assembly processes are poorly characterized and represent a large source of defects. This paper describes a successful cultural change toward predicting and optimizing product designs for factory assembly. It introduces the benchmarking concept for similar products and illustrates some key concepts--including the application of Boothroyd and Dewhurst methods--required for success. A specific product example is presented showing results of that effort.

Design for assembly is more a philosophy than a strict number crunching exercise. The advantage of providing a quantitative method for analyzing designs for assembly provides an ability to really evaluate different approaches in an objective manner. Perhaps the most important advantage is that in developing a total design concept to the point where it can be analyzed for assembly makes the product designers and manufacturing engineers really think through the total product.

In the implementation of a DFA culture it is important to pick a project which can be successful and leverage those results into other projects through benchmarking of product and production variables. Some of the issues and variables believed to be important are shown. The technical press abounds with success stories which can be used to help change the culture. Successful culture change requires changing behavior which requires motivation and training.

Brenneman, Allen and Robert Cunningham, Miles Labs, "Simultaneous Engineering of Medical Diagnostic Systems," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

The development of Medical Diagnostic instruments require the simultaneous design and manufacturing engineering not only of the electromechanical components of the system (i.e., the instrument) but also the simultaneous development of the chemistries and instrument since the end product we produce is a diagnostic system that returns a clinically significant result to the user.

This paper deals with the experience we have had in developing diagnostic systems and how we are integrating the entire development process from the chemistries to the instrument. Key to this process is the team concept that includes R&D Engineering, Advanced Manufacturing Engineering, Marketing, QA, Reagent R&D, Reagent Manufacturing, Material Control, Purchasing, Customer Service and at times vendors. In addition it covers the implementation of Design for Manufacture and Assembly into our Diagnostic product cycle.

Brown, Warren, "GM's Saturn Corporation Steers New Course," *The Washington Post*. Business Section, 28 August 1988.

Saturn's decision to put less whizbang technology in its plants indicates flexibility and maturity. Roboticized manufacturing palaces in Michigan and elsewhere showed GM that new machines do not always produce desirable results.

GM's experience at New United Motor Manufacturing, Inc. in Fremont, California, where it is producing cars with Toyota Motor Corporation, showed that better management of people and better supplier relationships tend to yield better-quality cars.

Saturn, as a result, has shifted its emphasis from machines to people in carrying out its main stated mission: "to design and manufacture vehicles in the U.S. that are world leaders in quality, cost, and customer satisfaction."

Burke, Gerald and Jamie Carlson, Ford Motor Company, "DFA at Ford Motor Company," *Proceedings of the Fourth Annual Conference on Product Design for Manufacture and Assembly*, Newport, RI, June 1989.

CALS/Concurrent Engineering Survival Kit, published in conjunction with The 2nd Annual User/Industry Conference on Computer-Aided Acquisition and Logistic Support CALS/CE, "Winning Business with CALS Phase II/Concurrent Engineering," Washington, DC, 24-25 September 1990.

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Canan, James W., Senior Editor, "Producibility," *Air Force Magazine*, October 1986.

Without top-to-bottom improvements in manufacturing technology, defense factories of the future will not be able to produce the required systems at affordable prices.

Carter, Donald E., "Concurrent Engineering: The Design Environment for the '90s," *Mentor Graphics Corporation*, Beaverton, Oregon.

Chang, Kang J. and Larry Lichten, California State University, "Tightly Coupling Rule-Based Process Planning with Computer-Aided Design, *Proceedings of The Second National Symposium on Concurrent Engineering*, Morgantown, WV, 7-9 February 1990.

Process planning plays a key role in factory automation by integrating CAD with manufacturing functions. By identifying manufacturing processes during design, manufacturability and cost analyses may be performed early in a product's life cycle, thereby increasing productivity. Toward this end, we describe a methodology for rule-based automated process planning for machined parts, which can

- link directly with computer-generated geometric modes
- assist designers in overcoming their lack of manufacturing knowledge
- generate sufficient information for process planning
- provide information to other manufacturing activities, such as numerical control, scheduling, tooling, and fixture design.

Christakis, Alexander N., *High Technology Participative Design: The Space-Based Laser*, Center for Interactive Management, George Mason University, Fairfax, VA.

The arena of high-technology design is inherently complex. It requires a variety of inputs from diverse knowledge disciplines and fields. When a group of experts engages in system design, new problems emerge for the designer(s) of having to cooperate with other designers. Yet, without the simultaneous participation of other designers, the "Law of Requisite Variety" will be violated. Each participant designer is expected to learn to cooperate with other designers and to appreciate the pluralities of realities relevant to the object of design. Yet each designer is physiologically and/or psychologically constrained by the "Law of Requisite Parsimony." These two fundamental laws of design are superficially incompatible or contradictory to each other. For the efficient conduct of participative design, the two laws must be reconciled. The paper discusses how the application of the Interactive Management (IM) approach reconciles this contradiction. A specific application of IM to the conceptual design of a space-based laser system is presented.

Clausing, Don, Massachusetts Institute of Technology, "Taguchi Methods to Improve the Development Process," *1988 IEEE*, pp. 826-832.

Product development in the U.S. needs to be faster, with the resulting products higher in quality and lower in cost, to be internationally competitive. Dr. Taguchi has developed powerful combinations of engineering, statistics, economics, and information theory that greatly improve product development. Product parameter design optimizes the nominal values of design parameters to keep performance near complete customer satisfaction despite variances of parts and environment. Tolerance design selects the basic precision level that minimizes total cost. Process parameter design optimizes process parameters to maximize the intrinsic stability of production. On-line QC periodically checks and adjusts production to maintain operating precision that minimizes total cost.

Clausing, Don P., Xerox Corporation, "Product Development Process," *1985 IEEE*, pp. 896-900.

The 10-step generic product development process is described, with emphasis on activities to achieve competitive position. Special attention is given to actions that can strongly improve common U.S. practice. Although most engineers are doing product development, the complete process receives little systematic study. Stronger emphasis on the complete product development process offers many opportunities for improvements.

Clausing, Don P., Xerox Corporation, "Quality Development for Minimum Total Cost," General Interest, Session C.

Production processes, such as electroforming, produce variations in the parts. Variations represent loss of quality and financial loss. Dr. Taguchi's methods, widely used in Japan, evaluate quality loss, develop stable processes, and provide best quality control during production. Dr. Taguchi's methods leads to high quality and low manufacturing cost.

Collins, James J., "Manage Technical Programs for Success," *Production Engineering*, April 1987, pp. 32-34.

This article presents a step by step procedure for the successful management of highly complex technical programs. The procedure stresses using a disciplined team approach and a goal-oriented focus, while keeping an eye on costs.

Concurrent Engineering Research Center (CERC), *DARPA Initiative in Concurrent Engineering (DICE)*, Factsheet, Morgantown, WV, February 1990.

Cortes-Comerer, Nhora, "Motto for Specialists: Give Some, Get Some," *IEEE Spectrum*, Part III, Organizing the Design Team, pp. 41-46, May 1987.

Parallel development of products and their manufacturing processes, within ever shorter lead times, is a formidable challenge for both designers and management. This article discusses how teams of diverse disciplines work in harmony to bring successful products to market.

Costello, Dr. Robert, The Under Secretary of Defense for Acquisition, *Concurrent Engineering - A Total Quality Management Process*, Memorandum for Secretaries of the Military Departments, Attention: Service Acquisition Executives, 9 March 1989.

Craig, Mark, "Managing Variation by Design Using Simulation Methods," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

In today's market, the product design engineering team has increased pressure to design a product for manufacturing and assembly efficiency as well as function. Statistical process control and design of experiments techniques have been widely implemented to identify, analyze, and control critical variation parameters in the manufacturing and assembly plant. These techniques, however, are used after the product is in production and do not provide the design engineering team with a method to predict variation during the design stage of a product, and thus prevent or control undesirable variation in production. In order for the design team to evaluate design and assembly proposals, before expensive tooling is committed, a simulation of the actual build process must be performed.

A method called Variation Simulation Analysis (VSA) provides the design engineer with the ability to evaluate the geometric effect of variation in an assembly due to component variation, processing relationships, assembly methods, and assembly sequence.

The VSA technique, properly integrated into an engineering organization, provides an effective tool to structure communication between design, manufacturing, assembly, and statistical process control.

A simultaneous engineering structure is created by using VSA to help manage the effects of variation during the design phase of a product.

Cullinane, Thomas P. (Northeastern University) and John Izuchukwu (Digital Equipment Corporation), "Implementing Concurrent Engineering," article and viewgraphs, presented at the Design for the Life Cycle Conference, Chicago, IL, 3-4 May 1990.

Daetz, Douglas, "The Effect of Product Design on Product Quality and Product Cost," *Quality Progress*, June 1987, pp. 63-67.

Focusing on quality and manufacturability during the development phase of a product's life cycle is crucial. The level of conformance quality that may be achieved in production and the product's cost are largely determined by the design of the product.

At this time, some of the key product design measures for achieving competitive quality and competitive product cost appear to be:

- designing product and process concurrently
- measuring and striving for assembly simplicity
- minimizing the number of parts
- minimizing the number of part numbers
- using as high a percentage of preferred parts as possible
- minimizing the number of vendors

These measures are not completely independent of each other, and as yet there has not been a systematic analysis to quantify their individual and joint contributions to both product quality and product cost. To a certain extent they may even seem to product development engineers to compound their problem of making tradeoffs in their designs in order to satisfactorily meet functionality, schedule, and other constraints. However, giving product development engineers explicit guidelines for making their design choices should make their job easier. The six measures listed above represent a start for focusing attention on the effect of product design on product quality and product cost.

The article discusses design teams of manufacturing/product/process engineers, the Design for Assembly (Boothroyd/Dewhurst) method and the Assemblability Evaluation Method (Hitachi/GE).

Davidson, Robert, Editorial Researcher, "Product Planners Assess Users' Needs," *IEEE Spectrum*, May 1987, pp. 29-32.

Designers of commercial, military, and consumer systems rely on the customer more than ever to help set design parameters.

DeVol, F.E., NCR Corporation, "Design for Manufacturability," *Proceedings of the Second Annual Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 April 1987.

Dewhurst, P. and G. Boothroyd, University of R.I., "Early Cost Estimating in Product Design," *Proceedings of the Second International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 April 1987.

This paper describes product costing procedures which are intended to form the basis for a design analysis method for Product Design for Efficient Manufacture (DFM). This DFM method, presently being developed by the writers, will form a logical extension of their Design for Assembly procedures, applications of which have already achieved major reductions in manufacturing cost in a wide range of U.S. industries.

Design for Assembly consists of two steps; the identification of the most appropriate assembly system for a new product design, followed by a careful analysis of the suitability of the design for the chosen assembly method. The more general aspects of design for efficient manufacture will consist of two analogous steps. The first step is the identification of the appropriate materials and manufacturing processes for the component parts of a new product design. The second step is the detailed design of the individual components consistent with the capabilities and limitations of the material-process combinations.

A prerequisite for making sound judgments in the choice of materials and processes is the availability of manufacturing cost information at the early product concept design stage. This implies the need to estimate manufacturing costs before component part designs are fully detailed and without full knowledge of the manufacturing processing plans. Such cost estimates must therefore be based on assumed optimum manufacturing methods irrespective of the processes and equipment which will actually be used. The present paper illustrates this approach for two important manufacturing processes; namely, machining and injection molding.

Eaton, Robert J., "Product Planning in a Rapidly Changing World," *International Journal of Technology Management*, Vol. 2, No. 2, 1987, pp. 183-189.

The paper addresses two major aspects of product planning: the technological challenge of assimilating rapidly developing technology into product design, and the marketing challenge of product differentiation for

shifting and segmenting markets. Both call for flexibility in planning and in manufacturing methods. To cope with this need for flexibility, the author recommends a return to the principles of Simultaneous Engineering--the breaking down of the traditional roles of Designer, Product Engineer and Manufacturing Engineer, and their re-integration into closely-knit and highly cooperative teams. Examples are given of the use of this approach at General Motors subsidiaries Opel, GM Trucks Group, Saturn Corporation, and Detroit Diesel Allison. Both the demands and the benefits of Simultaneous Engineering are assessed.

"The Efficacious Future for National Defense and the Nation Through Concurrent Engineering," article, presented at the Concurrent Engineering Task Force Meeting, 25 September 1989.

Fiksel, Joseph and Frederick Hayes-Roth, Cimflex Teknowledge Corporation, "A Requirements Manager for Concurrent Engineering in Printed Circuit Board Design and Production," presented at the Second National Symposium on Concurrent Engineering, Morgantown, WV, 7-9 February 1990.

Foo, George, AT&T, "Integrated Pull Engineering," *Design for the Product Life-Cycle Proceedings*, sponsored by The Manufacturing Institute, a division of Institute for International Research, Chicago, IL, 3-4 May 1990, pp. 1-6.

Over the last few years, the terms time-based competition and concurrent engineering have emerged as the latest buzzwords for enhancing competitiveness. Unfortunately, most previous discussions on these topics have been too vague or at too high a level to be of any value.

AT&T has been studying the product realization process, and has developed and tested a new concept known as Integrated Pull Engineering (IPE). IPE combines the best practices of concurrent engineering and Just-In-Time (JIT) to slash new product realization intervals by perhaps 40 percent. It is based on the following key concepts:

- Concurrency of design, manufacturing engineering, and material planning activities
- Synchronization of product realization (PRP) activities.

Forcier, Richard C. and Alfred D. Grant, "Systems Design Team: Personal Relationships in Instructional Development," *Educational Technology*, March 1973, pp. 58-59.

The team approach to instructional design and development would provide the most efficient and effective use of this talent.

Ganter, William A., Production Automation, Inc., "Quality in Design," *Quality and Reliability Engineering International*, Volume 4, John Wiley and Sons, Ltd., 1988, pp. 4-6.

This paper attempts to define a quality engineering role in the product design process. The product design process is also placed within the modern quality system. Methods of experimentation and modelling in design are emphasized and an example is described.

Garrett Engine Division, Allied-Signal Aerospace Company, *An Integrated Approach to Producibility*, viewgraphs.

Gatenby, David A., AT&T, "Design for "X" (DFX) & CAE/CAD," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

A key to efficient, profitable product realization is Design for "X" (DFX): Design for Manufacturability (DFM), Testability (DFT), Installability (DFI), Compliance (DFC), Reliability (DFR), and other downstream considerations. This paper presents DFX as a strategic concept for product realization, shows a systematic approach for understanding DFX, and describes techniques for supporting DFX to achieve corporate productivity and quality; CAE/CAD support of electronic and mechanical DFX is a key element of AT&T's DFX support strategy.

Gill, Allen, "Setting Up Your Own Group Design Session," *Datamation*, 15 November 1987, p. 88-92.

While group design techniques can't totally break the applications logjam, they can enhance systems usability by decreasing maintenance costs and improving productivity. Recommendations are given that can ensure getting the most out of team techniques when forming group design workshops. The article includes a discussion of IBM's Joint Application Design (JAD).

Gill, H., "Design for Manufacture-A Case Study," *Proceedings of the International Conference on Engineering Design, ICED 87*, Boston, MA, 17-20 August 1987.

In an effort to revitalize the manufacturing sector of the UK economy, the government and other agencies are investing large sums in advanced manufacturing technology. There is no parallel effort in investment in design and there are examples of endeavor to produce, more economically, that which should not be produced at all. This study is of a case where the company first addressed the design, designed-out the high cost manufacturing requirements and reaped that consequent benefit.

Godfrey, Richard G., TRW, "TQM-Concurrent Avionics Engineering," presented at the *SME Conference on Concurrent Engineering*, Viewgraphs.

Goranson, Ted, SAIC, "DARPA Initiative in Concurrent Engineering and Allied Programs," viewgraphs, presented at the Concurrent Engineering Task Force Meeting, 25 September 1989.

Goranson, H.T., SAIC, "Deep Structure for Activity Modeling," presented at the Second National Symposium on Concurrent Engineering, Morgantown, WV, 7-9 February 1990.

A key technology for concurrent engineering is in the area of high level conceptual methods for integrated product, process, and resource modeling. The underlying, unifying principles necessary are not well understood. A promising approach to working with these deep structural principles concerns the morphology of the grammars involved. Research in this area is outlined, and examples of new findings given.

Gordon, Fred and Robert Isenhour, United Research, "Simultaneous Engineering," *Management*, pp. 4-5.

For all practical purposes, American manufacturers traditionally approach the product development cycle in much the same way: sequentially. Each function, from design through manufacturing and all the way to distribution, taken one step at a time, in virtual isolation from its neighbors.

Recently, this restrictive tradition has come under close scrutiny by overseas competitors. Recognizing that product development can be a powerful driver of competitive advantage, they have shaken off the sequential legacy and are now beating American companies to the marketplace thanks to much shorter cycles.

Over the past few years, United Research has been working with several U.S.-based manufacturers to bolster their competitive abilities vis a vis product development. The process we used is known as simultaneous engineering. It ensures that the appropriate people within a corporation are brought into the development process at the appropriate time, regardless of a business' internal organization.

Gregory, William J., Coopers and Lybrand, "Examples of the Use of Design for Excellence Techniques to Improve the Product Development Process," *Design for the Product Life-Cycle Proceedings*, sponsored by The Manufacturing Institute, a division of Institute for International Research, Chicago, IL, 3-4 May 1990.

Guzzi, Maj. James F., USAF, "R&M Quality Team concept, A New R&M 2000 Initiative," *1988 Proceedings of the Annual Reliability and Maintainability Symposium*, pp. 277-279.

The Aeronautical Systems Division's C-17 System Program Office located at Wright-Patterson AFB, Ohio, has introduced a new project management initiative. This new initiative is designed to improve the effectiveness of a company's design organization to recognize and manage the Reliability and Maintainability (R&M) Program in day to day design activities. The new initiative which is called the R&M Quality Team Concept is the idea of Major James F. Guzzi, R&M Manager for the C-17 aircraft. This aircraft is presently being developed by Douglas Aircraft Company as the airlifter of the future. The new concept uses R&M Quality Teams and a Review Council, integrated with a structured approach to focus on System Level R&M issues. This new concept has been recognized by Industry and the U.S. Air Force as an "innovative approach" to successfully "influence" and "institutionalize" R&M management commitment throughout the total organization. The development of the R&M Quality Team Concept will be reviewed and summarized in this technical paper.

Hall, Donald, CALS Policy Office, "CE 201 Implementing the Concurrent Engineering Process," viewgraphs, presented at the CALS Phase II: Finding Practical Applications Conference, Costa Mesa, CA, 14-15 March 1990.

Hall, Donald, CALS Policy Office, "A Concurrent Engineering Tutorial," viewgraphs, presented at the Product Assurance Forum '90, Skylands at Randolph, NJ, 17-18 October 1990.

Halpin, John C., "The ASD Perspective on Concurrent Engineering," viewgraphs, presented at the Concurrent Engineering Task Force Meeting, 25 September 1989.

Hardwick, Martin, et al., *ROSE, A Database System for Concurrent Engineering Applications*, Technical Report No. 89062, Rensselaer Design Research Center, Troy, NY.

A database system for concurrent engineering should be efficient and should support mechanisms that allow users and applications to develop designs concurrently. The ROSE database system is efficient because it down-loads design versions into engineering applications in a way that allows those design versions to be processed at main memory speeds. The ROSE database system supports concurrency by allowing the differences between any two design versions to be computed as a delta file. These files can be used by users and applications to add the features of one design version to another design version. We describe why ROSE is efficient, how it computes the differences between design versions as delta files, and how its users and applications can use these delta files to transmit changes between design versions.

Haridim, Yosef, Northrop Corporation, *Requirements for Concurrent Engineering Information Architecture*, CALS/ISG/CE Framework Subtask Group, 1 May 1990 draft (written in March), to be released in mid-July, and 11 June 1990 draft.

The information architecture allows a multidisciplinary group to behave as an interdisciplinary team in a concurrent manner to create a product definition.

Harris, Diana and Scott Webb, "PWB Producibility CAD Tools," *Texas Instruments Technical Journal*, May-June 1988, pp. 19-27.

Webster defines *produce* as a verb meaning *to make or manufacture*. The suffix *-ability* means *having qualities of*. Putting the two definitions together, producibility is a characteristic or quality of a design that makes it capable of being manufactured efficiently and effectively.

Producibility Engineering was organized to optimize producibility in relation to other design conditions, such as electrical and mechanical functionality, test-ability, and reliability. Producibility Engineering provides specialized, expert production design engineering support and analysis to developmental programs throughout DSEG.

Hawiszczak, Robert, "Integrating Producibility Tools into a CAE Design Environment," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

Properly implementing producibility tools within a design process is a truly complex endeavor. It is this complexity that has slowed the integration of producibility tools throughout the design process. This paper seeks to unravel some of the mystery surrounding the relationship between producibility tools and the design process.

Competitive environments and corporate cultures have evolved unique design processes, and these basic design processes can be documented in standard procedures. Based on these standard procedures, disciplined design methodologies can be developed which meet organizational goals and permit the successful integration of automated CAE tools.

The next step is the development of an integrated CAE tools strategy which itself meets the requirements of the design methodology and considers automated producibility tools. Producibility tools can then become a formal part of the design process.

Producibility tools themselves can be developed with integration into the design process as a goal. Two producibility tools are reviewed to understand how each is being integrated within unique design methodologies. A model for integrated producibility tool development is presented. It defines the need for significant planning and design prior to the actual construction and use of any producibility tool.

Defining a logical, organized, disciplined design methodology is the key to success. Chaos can't be automated.

Hayes, Robert H. and Ramchandran Jaikumar, "Manufacturing's Crisis: New Technologies, Obsolete Organizations," *Harvard Business Review*, September-October 1988, pp. 77-85.

Getting beyond functional divisions, top-down decision making, piecemeal investment, and bottom-line accounting.

Hein, Lars, "Boosting Product Development Ability," *Proceedings of the International Conference on Engineering Design, ICED 87*, 17-20 August 1987, pp 195-236.

A new basic concept for the management of industrial product development projects has been formulated. Called "Integrated Product Development" its aim is to render the process an integrated, concerted action including R&D/Engineering, Marketing and Manufacturing.

A campaign to implement Integrated Product Development in Danish industries has been going on since spring 1985. The methods of implementation and the extent to which it has succeeded is briefly outlined.

At the present a research project, involving a number of industries, is being undertaken in order to expand the concept of Integrated Product Development. A procedure is created, by which product development can be restructured and dimensioned on the basis of the companies product strategy, marketing strategy and manufacturing strategy.

Hevner, A., A. Basu, M. Pecht, and B. Pourbabai, University of Maryland, "A Methodology for Concurrent Product Development with a Focus on Electronic Products," presented at the Second Annual Concurrent Engineering Symposium, Morgantown, WV, 7-9 February 1990.

This paper presents a research approach to define requirements and methods to support a new theory of systems management, for electronic product development process. Box structure theory and methods, which have proven quite successful in the development of computer-based information systems, are applied to a set of three framework hierarchies (the structure usage hierarchy of product design, the attribute hierarchy of product characteristics, and the process hierarchy of product management) for the technical and managerial requirements of electronic product development.

Hill, Capt. Raymond R., AFHRL, Wright-Patterson AFB, "Enhancing Concurrent Engineering Using Quality Function Deployment Based Tools," presented at the Second Annual Concurrent Engineering Symposium, Morgantown, WV, 7-9 February 1990.

This paper presents the use of Quality Function Deployment (QFD) as a means to improve the weapon systems acquisition process. QFD makes an ideal framework for a Decision Support System (DSS). The structure of the QFD matrices, coupled with the group processes required of QFD analyses, provide tremendous opportunities for application to CE.

Fundamental to this research is an understanding of the DoD initiatives in TQM and CE. We discuss TQM, its relationship to the American quality movement, and the fundamental tenets of TQM applicable to this research; TQM recognizes the need for increasing the focus on customer requirement. This TQM discussion leads naturally to discussing the DoD initiatives in CE. While TQM is a fundamental philosophy of acquisition management in the DoD, CE is a critical technology empowered to help meet the TQM goals of reduced cost, reduced schedule and improved performance.

QFD provides this necessary focus on customer requirements and is, in fact, commonly referred to as the *Voice of the Customer.* A focus on customer requirements, translated into DoD terms, means better definition of system requirements from the operational commands leading to better acquisition programs.

As a framework for a DSS and an extension to Systems Engineering, QFD provides a vehicle to enhance requirements definition, promote increased understanding of the requirements, provide traceability of the requirements, and correlate the requirements currently scattered among a myriad of acquisition documents. The benefits include: better program planning, improved requirements documentation, enhanced configuration management and control, and more efficient configuration audits.

Hock, Gerard, General Electric, "After Five Years, What has GE Learned from Design for Assembly," *Proceedings of the International Conference on Product Design for Assembly*, Newport, RI, 15-17 April 1986.

Hock, Gerard, General Electric, "Giving Your Designs a *Producibility Checkup*," presented at the *Second International Conference on Product Design for Manufacture and Assembly*, 6-8 April 1987, Newport, RI.

Hurd, Gary L., Cipher Data Products, "Design for Producibility," presented at the *Second International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 April 1987.

Huthwaite, Bart, Troy Engineering, "Product Design for Manufacture and Assembly: The Five Fundamentals," *Proceedings of the Second International Conference on Product Design for Manufacturing and Assembly*, 6-8 April 1987.

How a Product Design for Manufacture and Assembly (DFMA) effort is implemented is critical for its continued success. The following five fundamental steps are shown to be major keys to success.

- Map the current product design system, then map the new simultaneous engineering system, carefully identifying the new interfaces and roles required.
- Using previous product design cost and time data, create a profile of a typical product development. Create a new cost/time profile based on using simultaneous engineering and DFMA techniques. This idealized profile includes zero wait time between product development phases and includes only value-added engineering work.
- Set challenging quantitative benchmarks to be reached during specific time periods, based on data acquired in the preceding step.
- Provide training in DFMA design principles and techniques.
- Provide training in DFMA methodology (Boothroyd Dewhurst Method).

This paper is based, in part, on a recently completed pilot study on how companies are strengthening their manufacturing competitiveness through simultaneous engineering techniques and DFMA quantitative methods. Troy Engineering will complete the final study during late 1987.

Huthwaite, Bart with David Schneberger, *Design for Competitiveness, The Teamwork Approach to Product Development*, Advance Copy, The Institute for Competitive Design (ICD), Rochester, MI, 1990.

Huthwaite, Bart, Troy Engineering, "Product Design for Manufacture and Assembly. The Five Fundamentals," *Second International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 April 1987.

How a Product Design for Manufacture and Assembly (DFMA) effort is implemented is critical for its continued success. The following identifies five fundamental elements shown to be *major keys* to success.

This paper is based, in part, on a recently completed pilot study on how companies are strengthening their manufacturing competitiveness through simultaneous engineering techniques and DFMA quantitative methods. Troy Engineering will complete the final study during late 1987.

Huthwaite, Bart, *Design for Competitiveness, The Twelve Fundamentals*, Institute for Competitive Design (ICD), Rochester, MI, 1989.

Hyer, Nancy Lea (University of North Carolina, Chapel Hill) and Urban Wemmerlov (University of Wisconsin, Madison), "Assessing the Merits of Group Technology," *Manufacturing Engineering*, August 1988, pp. 107-109.

A survey of users indicates that group technology is most successfully applied when it is viewed as a general philosophy.

Hyer, Nancy Lea (University of North Carolina, Chapel Hill) and Urban Wemmerlov (University of Wisconsin, Madison), "Group Technology and Productivity," *Harvard Business Review*, July-August 1984.

Group technology (GT), the concept of exploiting similarities in recurring tasks and grouping like problems, is drawing increasing interest from manufacturers because of its ability to boost productivity in three ways: (1) by performing similar activities together, thereby cutting setup time; (2) by standardizing closely related activities, thereby eliminating unnecessary proliferation of similar parts; and (3) by storing and making accessible information related to recurring problems, thereby cutting time spent searching for information or solving problems.

GT is applied most often to purchased items and fabricated parts. Engineers use a classification system to group similar parts into "families" and assign each part a code. The code becomes the basis for scheduling and process planning. The most advanced application of GT is the creation of manufacturing "cells," which are collections of equipment grouped to process one or several part families. The advantages of cellular production include improved quality, reduced interferences, more efficient materials handling, reduced setup and run times, lower inventories, and shorter lead times.

GT can be combined with computer-aided process planning to create process plans more efficiently; it can help engineers standardize designs; and it can be used in purchasing, sales, and cost estimation.

Problems that may arise if the organization fails to adjust to GT include: conflicts with long-standing evaluation and reward systems; changing roles of operators and supervisors; a tendency for planners to lapse back to the old system; and codes unable to describe a part adequately.

Jancsurak, Joe, Senior Editor, "Redesigning a Hong Kong-Made Appliance Cuts Parts by 50 Percent," *Appliance Manufacturer*, Corcoran Communications, Inc., July 1988.

U.S. design team, taking part in our second annual DFM Roundtable, also reduces processes.

Johnson, Cynthia Reedy, "An Outline for Team Building," *Training: The Magazine of Human Resources Development*, Vol. 23, January 1986, pp. 48-52.

Cooperation, collaboration and communication are the ingredients of an effective team. Contains questionnaire/assessment scale.

Kaplan, Gadi, Issue Editor, "On Good Design," *IEEE Spectrum*, May 1987.

Katz, Isadore, Daisy Systems Corporation, "Automating Electronic Design," *IEEE Spectrum*, May 1987, pp. 55-66.

From architectural specification through design, verification, and layout, computer-aided engineering is changing the way EEs do their jobs.

Kelly, Dr. Michael, "DARPA Defense Manufacturing Office," viewgraphs, present at the Concurrent Engineering Task Force Meeting, 25 September 1989.

King, Resa W., "Engineering Made Easy, Thanks to Igor and Friends," Science and Technology Section, *Business Week*, 3 September 1990, pp. 103-104.

How Sikorsky and others are taming oceans of computerized data.

Krishnan, V., D. Navinchandra, P. Rane, and J.R. Rinderle, *Constraint Reasoning and Planning in Concurrent Design*, CMU-RI-TR-90-03, The Robotics Institute, Carnegie-Mellon University, Pittsburgh, PA, 7 February 1990.

By concurrent design we mean, in part, concurrent consideration of a broad range of life-cycle constraints concerning, for example, manufacturing and maintenance. The multitude of constraints arising from these considerations make it difficult to identify satisfactory designs. An alternative to explicitly considering all constraints is to determine which of the constraints are relevant, redundant or inconsistent and to consider only those which impact design decisions.

The proposed approach is based on two simple ideas: (1) constraints provide a uniform representation for a variety of life-cycle concerns; and (2) interval methods applied to constraints can be used to identify critical constraints, eliminate redundant constraints and to narrow the space of design alternatives.

The application of the necessary and sufficient intervals of constraints and constraint propagation techniques are used to classify constraints in this way and to focus design activity. Regional monotinicity properties are used to identity critical constraints.

A related aspect of concurrent design problems is the large number of complex constraints which have to be satisfied to complete a design task. As it is impossible to guarantee the simultaneous solution of a large set of design constraints, we have investigated algorithms for planning and simplifying such constraint problems.

Leaf, Dawn M. and William J. Chase, Westinghouse, "Rapid Acquisition of Manufactured Parts (RAMP)," *Society of Manufacturing Engineers (SME) Autofact '88 Conference Proceedings*, Chicago, IL., 30 October - 2 November 1988.

RAMP is a proof-of-concept manufacturing system designed to reduce cycle time in the delivery of spare printed wiring assemblies (PWA's). RAMP is a marriage between only the most essential manufacturing business functions and an integrated electronic assembly cell. Basic functions of order placement, work center control and material management drive automatic assembly through the following integrated subsystems:

Administrative Support Computerized System, Expert Manufacturing Data Generation System, Work Center Controller, Automatic Storage and Retrieval System, Containerization Work Station, DIP Kitting Work Station, DIP Assembly Work Station, Computer Aided Manual Operations Work-Station, and the Inspection Data Entry Work Station.

Leavitt, Don, "Team Techniques in System Development," *Datamation*, pp. 78-86, 15 November 1987.

Group design techniques provide orderly ways for business professionals to work together in small groups with the IS department in order to decide upon and understand the scope and content of a proposed system. While many focus on the design phase of the development cycle, a few start even earlier by attempting to bring structure and teamwork to strategic planning.

Actually, "facilitated team techniques" is a more useful and accurate term for these methods, since in every case, specially trained leaders are used to encourage and shape the work of the group formed to meet a perceived need. during group sessions, nontechnical end users and information systems staff meet on a common ground to gather information and hammer out system solutions that truly meet the needs of everyone--especially the needs of end-user management. The article discusses WISE Integrated System Development Method (WISDM), by Western Institute of Systems Engineering Corp., IBM's Joint Application Design (JAD), and METHOD by Performance Resources.

Lee, Dona M., Newport News Shipbuilding, Marketing-ILS Projects, "Concurrent Engineering: A Logistics Perspective," viewgraphs, presented at the Society of Manufacturing Engineers (SME) Conference on Concurrent Engineering, Arlington, VA, 3 October 1990.

Lien, Professor Terje Kristoffer, "Integration of the Product Design and Process Development Activities - A Case Example," *Proceedings of the Second International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 April 1987.

The traditional sequence of product and process development often misses the opportunity of taking advantage of new methods in production and automation. The paper describes an integrated approach that lets the product and the process develop in parallel, to integrate the latest knowledge of production methods in the product design. An example from a manufacturing company demonstrates the effect of this approach.

Longuemare, R.N., "Concurrent Engineering Defense Manufacturing Board Summer Study Panel, CALS/CE ISG," viewgraphs, presented at the Concurrent Engineering Task Force Meeting, 25 September 1989.

Martin, John M., Writer and Consultant, "The Final Piece to the Puzzle," Special Report, *Manufacturing Engineering*, September 1988, pp. 46-51.

You would think it was the most obvious thing in the world. When you are developing a new product, consider, along with all that product's functions, features, and cosmetics, how on earth you are going to make it.

Yet, shockingly, until perhaps about a year ago, only a relatively small number of forward-thinking companies were bringing their manufacturing organizations into the product development process at an early enough stage to significantly impact the concept, design, and subsequent manufacturability of the product.

Martin, John M., Consulting Editor, "Data Transfer Heats Up Out West," *Manufacturing Engineering*, March 1989, pp. 47-49.

The primes are increasingly skipping the blueprint stage when they pass their part geometry to contractor shops.

Martinez, Carlos Domingo, "The Human Factor in Design," *MacWEEK*.

Designing a product for manufacture requires a high level of communication and coordination among those involved in the process.

McAuley, Jack, IBM, "Case Study: IBM Product cycle Management, viewgraphs, *Design for the Product Life-Cycle Conference Proceedings*, sponsored by The Manufacturing Institute, a division of Institute for International Research, 3-4 May 1990, Chicago, IL.

McCarthy, Dan, "Goal Oriented Application of Design for Manufacturing (DFM)," North American Philips Corporation.

McGrath, Michael F., Office of the Secretary of Defense, "CALS, Enabling Process Improvements," viewgraphs, *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, pp. 212-220, viewgraphs.

McLinn, James A., McLinn, Dale & Associates, "Product Reliability: Extending Quality's Reach," *Manufacturing Engineering*, September 1988, pp. 52-55.

Reliability is created through the optimum combination of design, component parts, and manufacturing process.

Meyer, Stephen A., "Integrated Design Environment-Aircraft (IDEA), An Approach to Concurrent Engineering," McDonnell Douglas Helicopter Company, presented at the American Helicopter Society Forum, Washington, DC, 21-23 May 1990.

Successful rotorcraft development integrates conflicting design criteria, complex geometry, intricate manufacturing processes and detailed support methods. It involves a long design cycle, elaborate subsystem interactions and enormous quantities of data. The evaluation of these issues as design criteria during development is an application of the systems approach to design, now commonly known as Concurrent Engineering. This occurs when there is simultaneous design and optimization of the product, its manufacturing processes and support processes.

World market pressures, a shrinking defense budget and desire by the customer warrant rotorcraft development based on the philosophy of Concurrent Engineering. Four features have been identified as essential elements of Concurrent Engineering. These are: a top-down systems engineering approach to organize a cross-functional development team; use of interdisciplinary work groups for integrated product and process design; employment of quality engineering methods for effective product and process optimization; and an integrated computer-aided-engineering environment with simulation to prove out downstream design criteria prior to production and provide information for swift decision-making.

In the LHX SuperTeam approach, a Total Quality Management plan during preliminary design sketches the classical Systems Engineering Management Plan; natural work groups comprised of representatives for the total system life cycle participate in the design effort; and first-time-quality methods are introduced early in conceptual design. Ultimately, a computer-based design management system termed the Integrated Design Environment-Aircraft is created. The database is employed to structure rotorcraft life-cycle product information to create an integrated weapons system database. Disparate dataforms and datatypes are captured, organized, manipulated and disseminated in a rapid and responsive manner.

Michel, F.J., "Lessons Learned by the Army Materiel Command," *National Defense*, April 1987.

Mistree, Farrokh and Douglas Muster, "Designing for Concept: A Method That Works," *Proceedings of the International Workshop on Engineering Design and Manufacturing Management*, the University of Melbourne, Melbourne, Australia, 21-23 November 1988, pp. 1-14.

In the future, information that is useful in designing will be available almost instantly in quantity and quality heretofore not possible. Designers will negotiate solutions to open problems in a computer environment that is characterized by user-friendly desk-top computers networked to much larger machines - machines with the capability to process symbols (words, pictures, numbers, logic) - and extensive data-banks. We assert that the principal role of an engineer in this computer environment is to make decisions associated with the design and manufacture of an artifact. We therefore introduce a big picture, namely, the concept of Decision-Based Design and an approach called the Decision Support Problem Technique that is being developed at the University of Houston. We make a distinction between "designing for concept" and designing for manufacture." In keeping with the goals of the workshop we rapidly cut the big picture down to size, namely, to designing for concept using Decision Support Problems. We highlight some of the principal issues associated with their development and use. We make clear as to what has been achieved and what is currently available for use by industry and in our classrooms.

Mistree, Farrokh and Douglas Muster, University of Houston, "Conceptual Models for Decision-Based Concurrent Engineering Design for the Life Cycle," presented at the *Second National Symposium on Concurrent Engineering*, Morgantown, WV, 7-9 February 1990.

We recognize the current trichotomous nature of design, manufacturing and maintenance--the three principal phrases in the life cycle of a product. In the view of most engineers, they exist in relative isolation, as consecutively arranged entities with only a limited number of tenuous connections between the phases of design and manufacturing, and manufacturing and maintenance, and virtually none between the phases of design and maintenance. We take exception to this reductionist view. We prefer a holistic systems view which permits us to conceptualize the three entities as the principal subsystems of a larger system with many more interrelationships and connections among them than the just-cited reductionist view. We have introduced an approach by means of which the life span of a product can be considered as a single entity, a seamless range of activities and events which start at that creative moment when a designer says "ah-hah" and end when someone declares the product to be garbage. We call this process of considering virtually simultaneously all aspects of the life cycle of a product, at the time it is being designed, concurrent engineering design for the life cycle.

We believe that the process of design, in its most basic sense is a series of decisions. We offer Decision-Based Design (DBD) as a starting point for the creation of design methods that are based on the notion that the principal role of an engineer, in the design of an artifact, is to make decisions. We

recognize that the implementation of DBD can take many forms; our implementation, at the University of Houston, is the Decision Support Problem (DSP) Technique. Our approach to engineering design is embodied in the DSP Technique with the inclusion of life cycle considerations in its extension.

In this paper, we provide an overview of DBD and the DSP Technique. We define and use certain terms that are old in the art, for example, terms such as design, manufacturing and maintenance, and assign to them specific meanings which emphasize their unique interactive relationships within DSD. We offer a definition of the relatively new term in design, namely concurrent engineering design for the life cycle. We introduce the emergent notion of Meta-Design, which we believe can be understood best in terms of the contrapuntal and, yet, complementary meanings we have assigned to the terms partitioning and decomposing, and system and environment. Finally, using the substance of these terms and notions, we present a conceptual model of the decision-based process of concurrent engineering design.

Miyakawa, Seii and Toshijiro Ohashi, Hitachi, Ltd., "The Hitachi Assemblability Evaluation Method (AEM)," *Proceedings of the International Conference on Product Design for Assembly*, Newport, RI, 15-17 April 1986.

Montgomery, Douglas C., Arizona State University, "Experiment Design and Product and Process Development," *Manufacturing Engineering*, September 1988, pp. 57-63.

Product quality begins at the engineering design stage, where experiment design for product and process development can have a significant impact.

Morley, Ian E. and Stuart Pugh, "The Organization of Design: An Interdisciplinary Approach to the Study of People, Process and Contexts," *Proceedings of the International Conference on Engineering Design, ICED 87*, 17-20 August 1987, pp. 210-222.

This paper brings together the works of Morely and Pugh in the context of total design, considering the evolution of the understanding of leadership skills in parallel with the emerging understanding of engineering design. Models of design have brought about effective communication between the authors and industry, and they are used as the catalyst to focus upon the difference in design team characteristics required in differing design situations. These differences are elaborated through a consideration of products being either conceptually static or dynamic. It concludes by firmly establishing a sound relationship between the work in the two areas.

Muster, D. and F. Mistree "The Decision-Support Problem Technique in Engineering Design," *The International Journal of Applied Engineering Education*, Vol. 4, No. 1, 1988, pp. 23-33.

Until recently, design was practiced almost solely as an art. A science of design did not exist. The real world, as it was viewed by engineers, could be characterized in terms of Newtonian science. It was a world of relative simplicity, continuity and systems in equilibrium with each other and their environments. The assumption that engineering systems were in equilibrium or a steady-state was the starting point of all analysis. Nonlinear behavior, discontinuities and processes that did not fit this assumption were treated as exceptions and allowances were made in the design of artifacts which displayed such characteristics. Designers favored sequential-action methods and approaches whose limitations were of little practical concern until the advent of the modern computer. Now, the problems confronting engineers are of a larger scale, a higher order of complexity and the pace of technology change sometimes outstrips our ability to use it effectively. In this milieu, engineers need a new approach to negotiating solutions to their problems, one which permits a designer to accept a superior, "satisficing" solution with confidence in lieu of the chimera of an optimal solution. The methods consonant with this approach must provide a designer with the means to partition the original problem in sufficiently simple terms that finding a solution is a manageable process and, at the same time, the formulated problem and its model must be a close-enough approximation of the real world that satisficing solutions yield useful results. In this paper, the Decision-Support Problem Technique is explained in terms of the four phases and six steps which constitute the authors' approach to design and by means of which they plan, organize, integrate and measure their progress in the design process.

Nash, Sarah H., *Catalog of Training and Education Sources in Concurrent Engineering*, IDA Document D-666, Institute for Defense Analyses, Alexandria, VA, November 1989.

This document contains information on training and education programs and their courses in concurrent engineering or in methods supporting concurrent engineering. Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements.

This catalog contains 75 entries describing 119 programs with some entries having multiple programs. Of these, 6 are Associate Degree programs, 17 are Bachelor Degree programs, 33 Master Degree programs, and 22 are Ph.D. programs. Three Certification programs are listed as well as 37 Continuing Education programs and one post-graduate program.

Nevins, J. L., and D. E. Whitney, "What Progressive Companies are Doing to Raise Productivity," Charles Stark Draper Laboratory, Inc. Paper, pp. 1-39, October 1986, with attached presentation viewgraphs.

Advanced technology has long been the hope of companies wishing to raise their productivity, but now there is growing agreement that technology cannot accomplish this alone. This paper describes several strategies that stress integration of product design, process design, and total involvement of design and production employees. Such strategies allow rational mixes of technological and non-technological methods to be designed and justified.

The focus of these strategies is the assembly process. This process is inherently integrative and forces manufacturers to consider the widest range of issues, including part fabrication, functional and process tolerances, assembly, test strategies, vendor control, and the product's life cycle. Because of the ability of this approach to encourage simultaneous integration of so many factors that are so important, we call it the Strategic Approach to Product Design.

The Department of Defense faces several problems in attempting to foster this strategy among its suppliers. Some are generic problems in U.S. industry and universities while others are specific to DoD.

First, DoD and its suppliers do not engage in a sufficiently coordinated design and procurement activity. There are not enough mutual incentives to

contractors and DoD to improve productivity or to integrate product and process design.

Second, there are basic knowledge gaps and corresponding lack of design tools to support an integrated strategy. In parallel with these gaps is a lack of university curricula that would produce manufacturing and design engineers with the needed skills.

Third, companies and DoD lack interim methods for modifying their internal organizations so that they could take advantage of this strategy even in its currently empirical form.

Possible DoD options include (1) focussed studies to find ways to encourage more communications between users, suppliers, designers and manufacturers; (2) establishment of productivity institutes or centers of excellence devoted to creating integrative strategies and the supporting tools and research; and (3) innovative procurement and incentive plans that would imitate the commercial market's incentives.

Patterson, Mr. Michael, "Report on Army Concurrent Engineering Initiatives," Viewgraphs, presented at the Concurrent Engineering Task Force Meeting, 25 September 1989.

Pennell, James P. and Marko G. Slusarczuk, *An Annotated Reading List for Concurrent Engineering*, IDA Document D-571, Institute for Defense Analyses, Alexandria, VA, July 1989.

The purpose of this document is to provide an annotated bibliography on concurrent engineering. This document is intended to help the reader who is unfamiliar with concurrent engineering understand the several fields of study involved and also to allow those who are experts in some narrower subject gain an appreciation for work in related topics.

Pennell, James P. and William E. Akin, *An Examination of Various Methods Used in Support of Concurrent Engineering*, IDA Paper P-2318, Institute for Defense Analyses, Alexandria, VA, March 1990.

This is a supplement to IDA Report R-338, *The Role of Concurrent Engineering in Weapons System Acquisition*. The intended audience for this paper includes people who want to start using concurrent engineering within their projects or programs, managers who are considering how to use concurrent engineering, and research directors who are developing programs to provide the methods and technologies needed for concurrent engineering. This paper is intended to help them understand how the methods used in support of other concurrent engineering efforts could be beneficial to them. The data are the result of plant visits, reports from companies, and many conversations with engineers and executives from participating organizations. Although no company was surveyed in exhaustive detail, representatives from 18 different companies contributed to this study. The individuals and their sponsoring companies represent commercial as well as defense sectors in industries. The conclusions drawn are the result of the authors' assessment of the evidence and their judgement about its importance.

Perry, James L., "Unleashing the Power of Teamwork," *Government Executive*, July 1990, page 40.

Peyronnin, Chester A., "Keeping Contemporary With the Changing Nature of Interdisciplinary Design," *Proceedings of the International Conference on Engineering Design, ICED 87*, 17-20 August 1987, pp. 223-229.

This paper presents the changing composition of interdisciplinary design teams. Starting with simple cooperation between engineers, the paper gives examples of the problems presented by the addition of a broader spectrum of engineers, scientists, and social representatives and how they were resolved in selected situations. Lessons are then drawn from these examples.

Posner, Barry Z., "What's All the Fighting About? Conflicts in Project Management," *IEEE Transactions on Engineering Management*, Vol. EM-33, No. 4, November 1986, pp. 207-211.

The issues that are most likely to create conflict during a project and how the intensity of these disagreements varies over the life cycle of a project were investigated in this study. Also explored are the conflict management styles utilized by project managers and how these preferences are affected by individual and organizational factors (e.g., gender, age, managerial responsibilities, project size, and organizational structure). From a cross sample of organizations, 287 project managers were surveyed. Comparison with previous studies are noted.

Priest, John W., The University of Texas, "Producibility: Designing for Production," *1988 ASEE Annual Conference Proceedings*, pp. 308-310.

As American industries strive to manufacture products more efficiently, it becomes increasingly clear that a key factor to successful production is technological advances in manufacturing. One educational approach that can be used effectively to improve the current state of U.S. manufacturing technology is producibility. Producibility (or Design for Manufacturing) is an engineering discipline used to improve the relative ease of manufacturing an item. It is governed by the physical characteristics and features of a design and their implications on fabrication and assembly processes. In summary, producibility is an emerging engineering discipline directed towards achieving a design which is compatible with the realities of manufacturing.

Raine, J. K., "Design Innovation and Project Engineering--Paths to Profit," *Transactions of the Institution of Professional Engineers*, New Zealand, Vol. 13, No. 2/EMCh, July 1986, pp. 95-105.

Engineering projects today differ from those of yesteryear, both in the complexity of new technologies present, and the far greater number of components that comprise a complete system. There is a growing distinction between the creativity-intensive engineering of a new component or device, and the coordination and communication-intensive task of project engineering a large system. With the aid of intricate flow charts, this paper reviews the steps to success in the new product design process, and in the engineering of large system. Appropriate engineering organizations are outlined with pointers towards obtaining good performance from the engineering team. This article contains a value engineering flow chart.

Rao, Ashok, Neal Thornberry, and Joseph Weintraub, "An Empirical Study of Autonomous Work Groups Relationships Between Worker Reactions and Effectiveness," *Behavioral Science*, Vol. 32, 1987, pp. 66-76.

This paper reports on findings from an empirical study of 30 autonomous work groups. It deals with systems at the group level, particularly their producer and decider subsystems. Each work group operated within the same organization, making the same kind of product using the identical process. This study attempts to explain the differences between high productive and low productive autonomous work groups. The focus is on two key areas of worker perceptions: satisfaction with the job and perceptions of work group leadership. Results show the importance of establishing and communicating a policy of promotional opportunities to reward high performance. Leadership dimensions (superior orientation and consideration) that discriminate between high and low production groups are identified. These findings have implications in the selection and training of team leaders and the management of autonomous work groups.

Rawcliffe, Richard H. and Rick L. Randall, Aerojet ElectroSystems, "Concurrent Engineering Applied to an SDIO Technology Program," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 46-53.

Aerojet ElectroSystems is currently involved in the SPIRIT III Program to define and develop two major subsystems, an infrared focal plane array (FPA) and a radiometer analog signal processor (RASP). These subsystems will be integrated into an SDIO long-wave infrared sensor experiment to be launched in the early 1990s.

Aerojet has been tailoring Concurrent Engineering (CE) constructs to the company's business over the past year. SPIRIT III was chosen as a pilot for testing these new CE constructs because of the potential benefits in reducing cost and improving schedule while providing a state-of-the-art, high quality product. One of the key CE constructs, and the emphasis of this paper, is the use of multi-function teams that employ Quality Function Deployment (QFD) to enhance the definition of a solid set of product and process requirements based on the wishes of the customer. The context of multi-function team performance includes customer interaction with Aerojet Design Engineering, Program Management, and Product Development to evaluate the complex development, manufacturing, and test set of design and interface issues. Areas in which these issues exist include but are not limited to thermal, mechanical, electrical, environmental, performance, modularity, and interchangeability.

The SPIRIT III Program was selected as a pilot program to determine the benefits of CE and QFD and understand the impact of these tools within the Aerojet culture. A major subset of CE and QFD tools have been implemented, such as "House of Quality" Diagrams, Brainstorming, and Design of Experiment (DOE) or Taguchi experiments; results have been favorable.

The results and lessons learned of the partially complete SPIRIT III Program have provided Aerojet with the necessary information to initiate CE on additional programs and provide a better product to the customer.

"Realities of DoD Weapons Acquisitions," viewgraphs, presented at the Concurrent Engineering Task Force Meeting, 25 September 1989.

Reddy, Ramana, "Concurrent Engineering Research Center (CERC)," viewgraphs presented at the Second National Conference on Concurrent Engineering, Morgantown, WV, 7-9 February 1990.

Rehn, Gordon D., Deere Technical Services, "Simulation Applications in Manufacturing," *SME Autofact '88 Conference Proceedings*, 30 October-2 November 1988, Chicago, IL, pp. 35-52.

> The application of computer simulation in analyzing manufacturing problems has become more of a discipline than simply an analysis technique. Requirements for a successful simulation are described based on the experiences and resulting implementation philosophies of Deere and Company. A case study describing several interrelated simulation studies used in support of a recent factory expansion/modernization project is included. Manufacturing simulation applications include: design specification of material handling and process equipment; verification of programmable control logic; integration of detailed production operating strategies; implementation of incentive payment plans, and application of potential problem analysis.

Richter, W., "To Design in an Interdisciplinary Team," *Proceedings of the International Conference on Engineering Design, ICED 87*, August 1987, pp. 231-237.

> Advice and rules are provided for designers who want to work with good efficiency in an interdisciplinary team. This kind of work becomes gradually more important due to the increasing complexity of most products. A single designer who tries to handle the whole range of this complexity on his own is bound to fail sooner or later.

Scales, Charles D., Touche Ross and Company, "Transitioning From Design to Production-The Key to Performance in an Aerospace Development Environment," *Autofact '88 Conference Proceedings*, SME, Computer and Automated Systems Association, 30-October - 30 November 1988, Chicago, IL, pp. 3-29 - 3-43.

> In today's aerospace and defense development environment, the transition from design to manufacturing has come under close scrutiny. Much has been written about the use of computer-based technology to provide critical linkages between the two functional areas. But technology is not enough. The implementation of technology can require changes in organization structure and operating procedures. A framework is presented which engineering and manufacturing companies can use to assess their abilities to make a smooth transition from design to production. The framework is illustrated with numerous case examples from consulting engagements in development environments.

Schmaus, Thomas and Wolf-Dietrich Schneider, "Design for Assembly in West Germany - Experience and Trends," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

> Over the last few years German firms have been concentrating their efforts at rationalization increasingly on the area of assembly tasks. The aims pursued in this connection have by no means been restricted to assembly automation, they have also included a basic reduction in the time spent on assembly. It has become increasingly evident, however, that product design is vitally important to this objective. In the industrial projects of the Fraunhofer Institute IPA, in which automation of assembly tasks is planned, 75 percent of the products in the projects are modified or even completely redesigned. The product design measures are achieved by the

greater exchange of knowledge between the various experts which results from teamwork in firms. Computer-aided systems play a vital role in this. Numerous examples demonstrate that this method of procedure is efficient, and that in the area of product design for assembly German industry compares favorably with its international competitors.

Organizational planning and design decisions are typically quite complex, involving multiple decision makers with diverse perspectives, competing priorities, and large amounts of information. A group decision support system (GDSS) is of great benefit in these situations by using information technology to structure, facilitate and document the decision making process and by providing a framework for coalescing input from various decision makers and offering feedback on the implications of their assumptions. A case study of a decision conference (an intensive form of GDSS) held for the New York State Insurance Department demonstrates the advantages of decision modeling and information technologies used to improve the decision-making process, and also exemplifies the distinction between decision support systems (DSS) and GDSS.

Schrage, Daniel P., Georgia Institute of Technology, *Design Synthesis and Analysis, A Key to Concurrent Engineering Opportunities During the DoD Acquisition Process*, White Paper.

Semich, J. William, Economics Editor, "Designing for Quality," *Purchasing*, a Cahners Publication, 19 January 1989.

In the real world, the only way to guarantee quality products at the lowest cost is to design quality parts and processes before production even starts.

Sepehri, Mehran, "Manufacturing Revitalization at Harley-Davidson Motor Co.," *Industrial Engineering*, August 1987, pp. 87-93.

Setup times, inventory turns reduced.

Shad, Shabbir and Jane Haga, LTV Aircraft Products Group, "Teamwork for Excellence," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 62-72.

Teamwork for Excellence (TEX) is a company-wide process for change at LTV Aircraft Products Group (LTVAPG). It is the means by which we are integrating a total quality philosophy into strategic business planning for continuous improvement. Through implementation of the TEX Process, we are attempting to build an environment of excellence. This environment is envisioned as a place where employees are proud to work, where conformance to customer requirements is the only acceptable result, and where continuous improvement and innovation are a way of life. Such an environment depends on open communications among all employees, teamwork and individual involvement in the business.

We, like many other U.S. firms did not embark on such a formidable effort by choice, but rather by necessity. Our move was driven by significant changes in a dynamic marketplace. Our response was the development of a new business strategy which focused on modernization, technology, and excellence as a means to secure competitive advantage. The Teamwork of Excellence Process is the means by which we are pursuing this excellence strategy element.

The paper first describes the background and implementation approach of LTVAPG's TEX Process. It outlines our long-range plan for implementation including the assumptions, principles, goals and strategy. It then focuses on the Measurement and Reporting System, which indicates whether or not our continuous improvement efforts are successful. It concludes with a summary of the lessons learned in implementing total quality management in an aerospace and defense company.

Shunk, Dan L. and Richard D. Filley, "Systems Integration's Challenges Demand a New Breed of Industrial Engineer," *Industrial Engineering*, pp. 65-67, May 1986.

The authors make several recommendations for the successful introduction of system integration into an organization's corporate culture. Among these are:

- Recognize that people not technologies, are the key to success
- Make system integration an interdisciplinary team effort

The decision-makers from operations, MIS, finance and top management must be supporters, if not team players, on any major effort to make systems integration a part of a corporation's culture.

Simansky, Gary and George LeMoine, Pitney Bowes, "Design for the Future," the *Fourth International Conference on Product Design for Manufacture and Assembly*, Newport, RI., 5 June 1989.

Sines, R. Kelly, "Integrating Simultaneous Engineering Into New Product Introduction," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

Focusing on quality and manufacturability during the development phase of a product's life cycle is crucial. The level of quality that may be achieved in production and the product's cost are largely determined by the design of the product. The key product design measures for achieving competitive quality and competitive product costs are:

- Designing product and process concurrently
- Measuring and striving for assembly simplicity
- Minimizing the number of parts and levels within the structure
- Using as high a percentage of preferred parts as possible
- Minimizing the number of suppliers

The ultimate goal is to marry the above measures into the product development stage using a team concept and input from suppliers and the factory floor.

Slusarczuk, Marko M.G., Compiler and Editor, *Presentations at the Institute for Defense Analyses Concurrent Engineering Workshops, May-June 1988*, IDA Document D-572, Institute for Defense Analyses, Alexandria, VA, prepared for Office of the Assistant Secretary of Defense for Production and Logistics (OASD(P&L)), June 1989.

The purpose of IDA Document D-572 is to present the unedited viewgraph and handout materials provided by speakers at a series of workshops sponsored by the Institute for Defense Analyses (IDA) in May and June of 1988. The workshops were attended by approximately 100 invitees from government, industry, and academia, and examined issues related to concurrent engineering. The workshops served as important input to IDA Report R-338, *The Role of Concurrent Engineering in the Weapons System Acquisition Process.*

"Smart Design, Quality is the New Style," *Business Week*, 11 April 1988. pp.102-117.

"A Smarter Way to Manufacture," *Business Week*, 30 April 1990, pp. 110-117.

Sprague, William R., Sr. and John M. Wallach, "Design for Manufacturability Implementation and Elements for Success," *Proceedings of the Third International Conference on Product Design for Manufacture and Assembly*, Newport, RI, 6-8 June 1988.

> Industry is recognizing the value of Design for Manufacturability (DFM) as a strategy for competitiveness. To achieve significant results, two major obstacles must be overcome. First is how to implement a major cultural change to an organization and gain acceptance of it. The second is how to blend the tools and design process changes in the right strategic mix to maximize development effort. This paper examines how NCR Corporation and their Cambridge, Ohio plant have approached and succeeded with DFM by addressing these two issues.

Stauffer, J.L., Townley Engineering, Inc., "Product Design for Finish Quality," *Manufacturing Engineering*, September 1988, pp. 75-77.

> Anticipation, during product design, of some common part configuration pitfalls could eliminate many finishing problems that result in poor quality products or high production costs. A consideration of the following difficulties--at design stage--may ensure a superior product. Each finishing process has short-comings for certain configurations, and a thorough knowledge of the limitations of each method will help the designer to assure maximum finish quality in the end product.

Stauffer, Robert N., Executive Editor, "Unattended Machining Gets Increasing Attention," *Manufacturing Engineering*, March 1989, pp. 43-45.

> An Air Force ManTech effort aims to improve the productivity and competitiveness of small machine shops.

Stauffer, Robert N., Executive Editor, "Converting Customers to Partners at Ingersoll," *Manufacturing Engineering*, September 1988, pp. 41-44.

> Simultaneous engineering, along with transitional and continuous improvement efforts, comprise Ingersoll's ambitious partnership program.

Thamhain, Hans J. and David Wilemon, "Building High Performing Engineering Project Teams," *IEEE Transactions on Engineering Management*, Vol. EM-34, No. 3, August 1987, pp. 130-137.

> This article summarizes four years of research into the drivers and barriers of effective teambuilding in engineering work environments. A simple input-output model is presented for organizing and analyzing the various factors which influence team performance. The field survey results supported by correlation analysis indicate that team performance is primarily associated with six driving forces and six barriers which are related to leadership, job content, personal needs, and general work environment. Specific recommendations are made.

Thompson, Russ D., Ingersoll Milling Machine Company, "Simultaneous Engineering," viewgraphs, presented at the Design for the Product Life Cycle Conference, Chicago, IL, 3-4 May 1990.

Tierney, Carol, "Case Study: General Dynamics Land Systems," General Dynamics Land Systems, viewgraphs, *Design for the Product Life-Cycle Conference Proceedings*, sponsored by The Manufacturing Institute, a division of Institute for International Research, Chicago, IL, 3-4 May 1990.

Tracy, Michael J. (Peat Marwick Main and Company) and Donald H. Turner (Arthur Young), "Implementing CIM: Top Down Integration or Bottom Up Islands of Automation?", *SME Autofact '88 Conference Proceedings*, Chicago, IL, 30 October - 2 November 1988, pp. 1-12.

> Major questions are facing manufacturers throughout the United States and Canada regarding the best approach for implementing CIM in their operations. Should an approach using top down integration or a more laissez faire approach that stresses bottom up islands of automation be used? What are the advantages, disadvantages, and risks of each approach? What are the financial implications? How does my industry and size affect my decision? This paper examines these questions, focusing on differences faced by manufacturers of different sizes and industries. Case histories of actual manufacturers are used as examples.

Trevelyan, Jon, Computational Mechanics Inc., "Improving Productivity and Product Quality by Using Analysis to Guide Design," *SME Autofact '88 Conference Proceedings*, Chicago, IL, 30 October - 2 November 1988, pp. 15-21.

> Computer aided engineering (CAE) in the automotive industry has suffered in recent years from the competitive nature of the business. There is not time for engineers to experiment with ideas, and so their creativity is limited. This paper describes a technique which allows greater flexibility and a higher degree of automation in CAE, and shows how analysis of this type can guide the design and thereby promote an improved reliability and enhanced productivity.

Turner, Joshua U., Rensselaer Polytechnic Institute, "Automated Tolerancing Using Solid Modeling Technology," *SME Autofact '88 Conference Proceedings*, Chicago, IL, 30 October - 2 November 1988, pp. 13-22.

> The tolerancing of parts in assemblies is important to overall product quality and cost. The incorporation of automated tolerancing capabilities with existing CAD systems, is an important piece of the integration puzzle. This paper presents recent experience with the use of solid modeling technology to automate the tolerancing process. Methods have been developed that are automatic; can solve three-dimensional tolerancing problems; can be applied on a worst-case or statistical basis. Both geometric and dimensional tolerances can be used. Several example problems are solved.

Utterback, James M. (MIT) and William J. Abernathy (Harvard), "A Dynamic Model of Process and Product Innovation," *OMEGA, The International Journal of Management Science*, Pergamon Press, Great Britain, Volume 3, Number 6, 1975, pp. 639-656.

> This article reports results from empirical tests of relationships between the pattern of innovation within a firm and certain of the firm's characteristics: the stage of development of its production process and its chosen basis of competition. The hypothesized relationships posed for the present investigation are a synthesis of prior research by the present authors on two distinct but complementary conceptual models of innovation, concerning respectively: the relationship between competitive strategy and innovation, and the relationship between production process characteristics and innovation. The empirical investigation is carried out with data available

from the Myers and Marquis study of successful technological innovation in five different industry segments.

The essential aspects of the hypothesized relationships are that the characteristics of the innovative process will systematically correspond with the stage of development exhibited by the firm's production process technology and with its strategy for competition land growth. As a more specific example these relationships predict that there will be coherent patterns in the stimuli for innovation (market, production or new technology); in the types of innovation (product or process, original or adopted, etc.) and in barriers to innovation.

The presently reported statistical evidence is decidedly favorable to the hypothesized relationships, even though the adaptations needed to implement tests with existing data introduce dependencies that limit conclusions which would otherwise be warranted. The broad implication is that strong and important relationships exist among the capability of a firm to innovate, its competitive strategy and the posture of its production resources.

Varney, Glenn, "The Future of American Organizations," An Interview with Marshall Sashkin, *Group & Organization Studies*, Vol. 12, No. 2, June 1987, pp 125-135.

The future of American management and the role organization development (OD) professionals play in organization change has emerged as a paramount concern to chief executive officers, managers, educational institutions, and many others in our society. This interview with one of the foremost thinkers on the subject of cultural and organizational change sets forth some very clear recommendations for improving American competitive positions in the world environment.

Vasilash, Gary S., "Simultaneous Engineering, Management's New Competitiveness Tool," *Production*, July 1987, pp. 36-41.

The concept is as simple as it is powerful: obtain as much information as possible as early as possible, then go to work creating world-class products and the processes that make them cost effective. But it isn't as easy as it may sound or seem.

More than a simple give-and-take between management and workers about the existing state of affairs, simultaneous engineering brings together groups that have historically had, perhaps, more friction between them than labor and management: design engineers and manufacturing engineers, or product and process people. What's more, they don't talk about givens; they must take concerted action on things that don't exist.

Their combined objective is, quite simply, to develop better products, whether it's a home appliance or an automobile. *Better* is expected to result from the fact that the two groups are working together. This may not seem to be extraordinary. After all, both groups are engineers; both groups work for the same company. It would be only natural that the two work in concert. But with few, relatively recent, exceptions, each group has operated in semi-impenetrable isolation within the major organizations.

Not only are the design and manufacturing people brought together, but there are a few more ingredients that really get the pot boiling. For example, the input from marketing and financial people becomes relevant to product and production decisions like never before. And the OEMs no

longer select suppliers to work to specs, but actually preselect suppliers who help develop the specs. Customers and vendors work together, sometimes even in the same office.

Voelcker, John, Associate Editor, "Learning From Earlier Systems," *IEEE Spectrum*, May 1987, pp. 67-72.

In product redesign to meet changing market requirements, exploit new technologies, or reduce manufacturing costs, conflicting demands must be balanced. When redesigning to correct flaws, add capabilities, or update aging features, figuring out what to keep and why is as important as knowing what to change.

Volkema, R.J., "Problem Formulation in Planning and Design: What We Know and What We'd Like to Know," Department of Engineering Administration, George Washington University, Washington, DC, pp. 91-95.

This paper summarizes what we know (or think we know) about problem formulation in planning and design, and raises questions for future consideration.

Wallich, Paul, Associate Editor, "How and When to Make Tradeoffs," *IEEE Spectrum*, May 1987, pp. 33-40.

Aircraft must be lighter, consumer products more functional, implantable devices more reliable--but at what cost?

Webster, LTC Douglas, Office of the Assistant Secretary of Defense, Production and Logistics, "The DoD Initiative in Concurrent Engineering," viewgraphs presented at the *Conference on Concurrent Engineering: A Practitioner's Look at Industry and Government Initiatives*, sponsored by the Society of Manufacturing Engineers, Washington DC Chapter and the Concurrent Engineering Research Center, 3 October 1990.

Whitney, Daniel E., Manufacturing by Design," *Harvard Business Review*, July-August 1988, pp. 83-91.

Strategic product design is a total approach to doing business. It can mean changes in the pace of design, the identify of the participants, and the sequence of decisions. It forces managers, designers, and engineers to cross old organizational boundaries, and it reverses some old power relationships. It creates difficulties because it teases out incipient conflict, but it is rewarding precisely because disagreements surface early, when they can be resolved constructively and with mutual understanding of the outcome's rationale.

Strategic design is a continual process, so it makes sense to keep design teams in place until well after product launching when the same team can then tackle a new project. Design--it must be obvious by now--is a companywide activity. Top management involvement and commitment are essential. The effort has its costs, but the costs of not making the effort are greater.

Whitney, Daniel E., Charles Stark Draper Laboratory, Inc., "Manufacturing and Design: A Symbiosis," *IEEE Spectrum*, May 1987, pp. 47-54.

If robots land other advanced assembly methods are to be used efficiently, products must be scrutinized in terms of manufacturability early in the design cycle.

Winner, Robert I., "The Role of Concurrent Engineering in Weapons Systems Acquisition," viewgraphs, Institute for Defense Analyses, Alexandria, VA.

Winner, Robert I., James P. Pennell, Harold E. Bertrand, and Marko M.G. Slusarczuk, *The Role of Concurrent Engineering in Weapons Systems Acquisition*, IDA Report R-338, Institute for Defense Analyses, Alexandria, VA, December 1988.

The purpose of this report is to document the results of a study made by the Institute for Defense Analyses (IDA) for the Department of Defense to assess claims of improved competitiveness in the commercial industrial base resulting from the use of concurrent engineering. IDA reviewed published documentation on concurrent engineering and its implementation in industry; conducted workshops to learn from industry of the various approaches being taken to increase competitiveness; and visited and held technical discussions with 14 major U.S. corporations on their successful experiences with the use of concurrent engineering. The IDA Report is the IDA study team's judgment of the consensus expressed by the groups of recognized experts.

Wood, Jonathan D. and Robert I. Winner, *The Relationship Between CALS and Concurrent Engineering*, IDA Paper P-2306, Institute for Defense Analyses, Alexandria, VA, 1 March 1990.

Concurrent engineering can be thought of as the integration of engineering effort while CALS is the integration of engineering information. There are two areas of explicit, shared interest between the two initiatives. These are multi-enterprise information frameworks and individual information exchange standards, discussed in sections 2.1 and 2.2. Conclusions and recommendations for further action are found in section 3. The Works Consulted section lists all of the documents used in this study. Appendix A contains a copy of the Taft memo which partially defines the CALS program. An article on concurrent engineering is reprinted in Appendix B.

Wroton, H.C. and D.A. Ruscio, Martin Marietta Astronautics Group, "Engineering Excellence and How it Relates to Product Excellence," *AIAA/ADPA/NSIA 1st National Total Quality Management Symposium, A Collection of Technical Papers*, Denver, CO, 1-3 November 1989, pp. 8-14.

Before we can achieve excellence in our products, it is mandatory that we achieve excellence in our engineering. Excellence in engineering means providing documents to the fabrication community that have (1) requirements that are constant and consistent with contract specifications; (2) parts that can be procured to schedule and have correct numbers; (3) tolerances that are established with consideration to the build process; (4) drawing presentations and definition that can be integrated and converted to the finished product. In other words, our engineering products must be error free. Engineering excellence must be accomplished before automation occurs.

Engineering excellence cannot be achieved by our traditional definition of engineering that describes the designer as the engineer. "Engineering" must be defined as all engineering personnel (i.e., design engineers, systems engineers, manufacturing engineers, product assurance engineers, etc.) who will be associated with the design, fabrication and test of the product. The team approach to producing engineering is essential for generating quality in our products.

This paper will discuss the transition from engineering excellence to product excellence as well as the status, initiatives, and implementation of the product excellence program in Martin Marietta's Space Systems Company. Performance measurement data from all the Martin Marietta Astronautics Groups will be presented.

Yuile, Kennth, "Making Converts: Success in Mechanical Assembly," *Third International Conference on Product Design for Manufacturing and Assembly*, Newport, RI, 6-8 June 1988.

Whitney, Daniel E., "Manufacturing by Design," Harvard Business Review, July-August 1988, pp. 83-91.

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Design Insight, The Quarterly Update on Design for Manufacture and Assembly, Volume 1, Numbers 1-5, Boothroyd Dewhurst, Inc., Troy Engineering.

Design for Manufacture Alert, An Intelligence Service for World Class Manufacturers, The Management Roundtable, Inc., August 1989, October 1989, and October 1990.

Focus, National Center for Manufacturing Sciences, Volume 3, Numbers 1-7, The Communications Services, Department of the National Center for Manufacturing Sciences, 1990.

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Abstracts of Papers presented at the Second National Symposium on Concurrent Engineering, Morgantown, WV, 7-9 February 1990.

CALS/CE Industry Steering Group Task Force, *Integrated Workshop Proceedings*, viewgraphs, National Institute of Standards and Technology, Gaithersburg, MD., 1-3 May 1990.

Design for the Product Life-Cycle Conference Proceedings, sponsored by The Manufacturing Institute, a division of Institute for International Research, Chicago, IL, 3-4 May 1990.

Emerging Prototypes for Concurrent Engineering, Proceedings of the Second National Symposium on Concurrent Engineering, Concurrent Engineering Research Center, Morgantown, WV, 7-9 February 1990.

Session 1: Information Modeling/Representation
Session 2: Integrating Framework for Concurrent Engineering I
Session 3: Integrating Framework for Concurrent Engineering II
Session 4: Architecture Utilities and Services
Session 5: Activities Modeling and Management
Session 6: Computer-Based Methods for Concept Evaluation I
Keynote Address: Emerging Prototypes for Concurrent Engineering
Session 7: Computer-Based Methods for Concept Evaluation II
Session 8: Quality Management Methods

List of Attendees

Proceedings of the International Conference on Product Design for Manufacture and Assembly, 1986, 1987, and 1988.

Proceedings of the International Conference on Engineering Design, ICED 87, 17-20 August 1987.

Society of Manufacturing Engineers (SME) Autofact '88 Conference Proceedings, Chicago, IL., 30 October - 2 November 1988.

REPORTS

CALS Technical Report 001, *Integration of R&M into the Automated Design Process, Report of the CALS R&M Summer Study on Complex Electronics*, 17 March 1988.

CALS Technical Report 002, *Application of Concurrent Engineering to Mechanical Systems Design*, Final Report of the R&M Mechanical Design Study, CALS Industry Steering Group, Washington, DC, 16 June 1989.

> This report describes one methodology for application of the practice commonly described as Concurrent Engineering to the design of Reliability and Maintainability (R&M) features in mechanical systems. The methodology consists of a structural roadmap to be used for transition from the current task oriented approach to more synthetic, and thus concurrent methods. Since the roadmap retains the terminology describing functions of R&M engineering as defined in current documentation, the transition is conceptually straightforward. It is intended that each engineering operation tailor the generic roadmap matrix presented in the report to best meet its specific goals and requirements. Several early returns indicate that the roadmap is an excellent tool for engineering process planning and investment scheduling. Thus, the report serves as a practical case study of an approach to the implementation of concurrent engineering at the detailed engineering process level that can be readily extended to other specialities. Integration and automated design synthesis of any specialty function, such as R&M are clearly self-justifying within or without the context of concurrent engineering. The report deals thoroughly with the issues of integration of R&M into the engineering process, including the cultural changes required and data requirements. It should be viewed as a contributor to the technology of concurrent engineering, but since it does not deal with the full spectrum of issues as described under the broad heading of concurrent engineering, it is not specifically a concurrent engineering report. It is intended to parallel while standing alone from other concurrent engineering activities.

The Pymatuning Group, Inc., *Industrial Insights on the DoD CE Program*, Rossyln, VA, October 1988.

> This report presents some first insights from a cross-section of industrial officials asked to consider DoD's newly-initiated Concurrent Engineering Program. Since the implementation of this program will take place principally in the laboratories of industry and on the production lines of industry, it is industrial managers and officials that must understand, support, and justify the costs of the associated changes to corporate management and corporate boards.
>
> At the same time, to the Defense Industrial Base, DoD is for all intents and purposes a "monopolistic" customer. DoD acquisition regulations, requirements, schedules, and audits govern the defense marketplace. It is DoD, therefore, that takes the lead in introducing changes that must be implemented by defense vendors as a sort of "entry fee" to the defense market.

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Andreasen, M. M. and L. Hein, *Integrated Product Development*, Springer-Verlag, New York, 1987.

Cleland, David I. and Harold Kerzner, *Engineering Team Management*, Van Nostrand Reinhold Company, New York, 1986.

Dertouzosl, Michael L., Richard K. Lester, Robert M. Solow, and the MIT Commission on Industrial Productivity, *Made in America: Regaining in Productive Edge*, The MIT Press, Cambridge, MA, 1989.

Hayes, Robert H., Steven C. Wheelwright, and Kim B. Clark, *Dynamic Manufacturing, Creating the Learning Organization*, The Free Press, 1988.

Nevins, James L. and Daniel E. Whitney, *Concurrent Design of Products and Processes, A Strategy for the Next Generation in Manufacturing*, McGraw-Hill Publishing Co., 1989

Olson, S.A., Editor, *Group Planning and Problem Solving Methods in Engineering*, John Wiley and Sons, New York, 1982.

Plossl, Keith R., *Engineering for the Control of Manufacturing*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1987.

Taguchi, Genichi, *System of Experimental Design, Engineering Methods to Optimize Quality and Minimize Costs, Volume One*, Don Clausing, Technical Editor for the English Edition, Unipub, Kraus International Publications, White Plains, NY and American Supplier Institute, Inc., Dearborn, MI, 1987.

Taguchi, Genichi, *System of Experimental Design, Engineering Methods to Optimize Quality and Minimize Costs, Volume Two*, Don Clausing, Technical Editor for the English Edition, Unipub, Kraus International Publications, White Plains, NY and American Supplier Institute, Inc., Dearborn, MI, 1987.

QUALITY FUNCTION DEPLOYMENT

QUALITY FUNCTION DEPLOYMENT

PAPERS/PRESENTATIONS

DeVera, Dennis, Tom Glennon, Andrew A. Kenny, Mohammed A.H. Khan, and Mike Mayer, "An Automotive Case Study," *Quality Progress*, June 1988, pp. 35-38.

> Eaton Corporation used an air conditioning part to clear the way for future QFD projects.

Flaherty, Thomas, Rockwell International Automotive Operations, "Quality Function Deployment, The Challenge of Implementation," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA., 4-6 December 1989.

Fortuna, Ronald M., Manager, "QFD Results," Ernst and Whinney, Chicago, IL.

GOAL/QPC Research Committee, "Quality Function Deployment: A Process for Continuous Improvement," Research Report No. 89-10-02, Methuen, MA, 1989.

GOAL/QPC Research Committee, "Quality Function Deployment: A Process for Translating Customers' Needs Into a Better Product and Profit," Research Report No. 89-10-02, Methuen, MA, 1989.

Hauser, John R. and Don Clausing, "The House of Quality," *Harvard Business Review*, May-June 1988, pp. 63-73.

Hayn, John W., viewgraphs, "Quality Function Deployment at the McDonnell Douglas Missile Systems Company."

Holusha, John, "Raising Quality: Consumers Star," *Business Day*, The New York Times, Thursday, 5 January 1989.

King, Robert, GOAL/QPC, "Listening to the Voice of the Customer: Using the Quality Function Deployment System," *National Productivity Review*, Summer 1987.

> In many of the cases reported, the use of quality deployment has cut in half the problems at the beginning (design) stages, shortened development time from one-half to one-third, all the while assuring users' satisfaction and increasing sales. However, if it is applied incorrectly, it could increase work without producing any good.

Langevin, Roger G., "SPC and the DoD," Quality Progress, September 1988, pp. 35-37

McDonnell Douglas Helicopter Company, viewgraphs, *An Introduction to Quality Function Deployment (QFD)*, Product Quality Processes.

McGaw, Kendall, "QFD in Pharmaceuticals, A Case Study," *Proceedings of the GOAL/QPC 5th Annual Conference*, Boston, MA., 4-6 December 1989.

> This paper is based on an actual case involving the development of a new *next generation* intravenous infusion pump. The words which follow attempt to give the readers a flavor of the experience so that they can hopefully become more efficient and effective in the QFD process.

Naughton, Jim, "Developing Tree Structures That Include Qualitative Characteristics," Expert Knowledge Systems, Inc., McLean, VA., May 1989.

Quality Function Deployment and the Seven Management Tools offer means to acquire, organize, and use the essential information needed to satisfy customer quality requirements. As these approaches are used beyond manufacturing application, there is an increased need to deal with a greater volume of qualitative information. The techniques that work well with quantitative information must be supported with additional techniques in order to effectively build trees and the other forms of information organization. This paper describes an overall approach to techniques for the inclusion of qualitative information in QFD projects.

Porter, Bob, Texas Instruments Inc., "Implementing QFD at Texas Instruments," viewgraphs *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA., 4-6 December 1989.

Quality Function Deployment, A Collection of Presentations and QFD Case Studies, American Supplier Institute, Inc., Center for Taguchi Methods, 1987.

Ross, Phillip J., "The Role of Taguchi Methods and Design of Experiments in QFD," *Quality Progress*, June 1988, pp. 41-47.

Taguchi Methods, design of experiments, and QFD are complementary tools that should be used during the off-line phase of a product or process life cycle.

Smith, Larry and Hal Schaal, Ford Motor Company, "Why Quality Function Deployment?," viewgraphs, *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA., 4-6 December 1989.

Sullivan, Lawrence P., "Policy Management Through Quality Function Deployment," *Quality Progress*, June 1988, pp. 18-20.

The idea is to strengthen the company through cross-functional product and policy deployment.

Thackerary, Ray J. and George Van Treeck, Digital Equipment Corporation, "Quality Function Deployment for Embedded Systems and Software Product Development," *Proceedings of the GOAL/QPC 6th Annual Conference*, Boston, MA., 4-6 December 1989.

This paper is specifically aimed at embedded systems and software development and discusses a technique by which the goals of higher quality, faster time to market and lower maintenance cost may be attained while at the same time better meeting customer requirements.

Product developers moving from sequential processes and into a mode called Simultaneous Engineering (sometimes dubbed *Concurrent Engineering*) where groups involved in product development and production all work on the design of the system in parallel. Developers must be ready to participate in this process.

QFD, or Quality Function Deployment, is a methodology that has enabled the transition from Sequential to Simultaneous Engineering. In embedded systems and software development projects, CASE (Computer Aided Software Engineering) tools are becoming ever more popular; this paper will demonstrate where QFD better facilitates the use of these tools, by describing a methodology and providing an example as an illustration.

Vora, Lakshmi S., Robert E. Veres (Ford Motor Company), and Philip C. Jackson (Inference Corporation), "Technical Information Engineering System (TIES)," *Autofact '89*, MS89-736, 30 October-2 November 1989, pp. 26-37 - 26-45.

TIES is a computer-assisted methodology to help achieve significant improvements in product quality by collecting and storing in the computer relevant engineering information, experience and knowledge from cross functional product and process design teams. TIES builds upon the foundation of Quality Function Deployment (QFD) through a knowledge based system approach to facilitate design decisions, resolution of cross functional issues, and retaining engineering knowledge. QFD is a systematic means of ensuring that the demands of customers and the market place are accurately translated into appropriate technical requirements and actions throughout each stage of product development. TIES fully supports the QFD process, QFD chart creation and updates, and QFD data analysis. TIES is an innovative application of Artificial Intelligence (AI) programming techniques to support and extend the QFD process. The arena of the TIES project overlaps computer technology, design and engineering methodology, TIES is deployed on Sun 4 workstations and TIE software is programmed using Automated Reasoning Tool (ART) from Inference Corporation and Command LISP. TIES is used in applications that vary from building a complete vehicle design QFD, to a component-specific one such as designing an instrument panel for a particular vehicle.

Vora, Lakshmi S., Robert E. Veres (Ford Motor Company), Philip C. Jackson, and Philip Klahr (Inference Corporation), "TIES: An Engineering Design Methodology and System," *Proceedings of the Second Annual Conference on Innovative Applications of Artificial Intelligence (IAAI-90)*, Georgetown University, Washington, DC, 1-3 May 1990.

Same abstract as above.

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King, Bob, *Better Designs in Half the Time, Implementing Quality Function Deployment (QFD) in America*, published by GOAL/QPC, Methuen, MA, 1987.

GROUP PROBLEM SOLVING

GROUP PROBLEM SOLVING

PAPERS/PRESENTATIONS

Adelman, Leonard, "Real-Time Computer Support for Decision Analysis in a Group Setting: Another Class of Decision Support Systems," *INTERFACES 14*, #2, March-April 1984, pp. 75-83.

> Real-time, decision-analytic aids developed to support group decision making are an important subset of decision support systems (DSS). They satisfy the basic requirement: provide interactive computer support for the decision making process by assisting decision makers in thinking about the various aspects of the decision problem(s) facing them. How a decision-analytic DSS was successfully applied to a military design problem and, more generally, why decision-analytic DSS effectively facilitate group decision making are discussed. Plot of "efficient frontier" as benefit vs. cost curve.

Adler, Paul S., "When Knowledge is the Critical Resource, Knowledge Management is the Critical Task," *IEEE Transactions on Engineering Management*, Volume 36, Number 2, May 1989, pp. 87-94.

> This paper argues that the increasing centrality of technology and other forms of knowledge to competitiveness induces long-run changes in both operations management and engineering management. Those emergent trends in practice are paralleled by changes in academia, in both teaching and research. In several domains of management practice, the *public good* nature of knowledge undermines the effectiveness of both market and planning models of organization, reinforcing of both market and planning models of organization, reinforcing the role of cooperation as a third mode of coordination. Researching the essential issues posed by such a change requires a paradigm shift from management science and operations research formulations to more qualitative, less analytical, and more inductive approaches.

AIRMICS, U.S. Army Institute for Research in Management Information, viewgraphs, January 1990.

Applegate, Lynda M., Benn R. Konsynski, and J. F. Nunamaker, "A Group Decision Support System for Idea Generation and Issue Analysis in Organization Planning," *Proceedings of the CSCW '86, Conference on Computer-Supported Cooperative Work*. August, TX, 3-5 December 1986, pp.16-34.

> The increasing reliance on group decision-making in today's complex business environments and advances in microcomputer, telecommunications and graphic presentation technology have combined to create a growing interest in the design of group decision support systems (GDSS). Planning is an important group decision-making activity within organizations. Effective planning depends on the generation and analysis of innovative ideas. For this reason, the idea generation and management process has been chosen as the domain for the study of the design and implementation

of a GDSS to support complex, unstructured group decision processes within organizations.

The MIS Planning and Decision Laboratory has been constructed to provide a research facility for the study of the planning and decision process while top executives from a variety of organizations use the laboratory to conduct actual planning sessions for their organization. This paper presents the design of a system to support the idea generation and analysis process in organization planning. Results of research conducted in the MIS Planning and Decision Laboratory on the use of the Electronic Brainstorming system with over 100 planners from a variety of organizations are presented and discussed.

The findings of the research indicate that computer brainstorming stimulates task oriented behavior, decreases group interactions and equalizes participation. Information presentation, network speed and typing skills of the upper level managers were identified as possible inhibitors of the idea generation process that must be considered in the design of the system and the methodology for its use. Planners using the GDSS reported high levels of satisfaction with the process and outcome of the planning sessions. They rated the computer as an important tool for idea generation and the computer brainstorming process as "Much Better" than manual brainstorming.

Argyris, Chris, "Interpersonal Barriers to Decision Making," pp. 121-134.

This article presents the major findings of a study of executive decision making in six representative companies. The findings have vital implications for management groups everywhere; for while some organizations are less subject to the weaknesses described than are others, all groups have them in some degree. The findings are discussed in detail and the implications for executives up and down the line are examined.

Ayres, Donna, Facilitator, Fort Belvoir Fusion Center, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

Begeman, Michael, Peter Cook, Clarence Ellis, Mike Graf, Gail Rein, and Tom Smith, "PROJECT NICK: Meetings Augmentation and Analysis," *Proceedings of the CSCW '86, Conference on Computer-Supported Cooperative Work*, Austin, TX, 3-5 December 1986, pp. 1-6.

This paper presents an overview of MCC's Project Nick, which is aimed toward the understanding and enhancement of meetings. One research focus is the preparation of information which is frequently done before meetings. For example, it is possible to create sophisticated diagrams and slides at one's workstation before the meeting and call them up on the electronic blackboard during the meeting. Another focus is the development of aids for the facilitator to use during the meeting. For example, the facilitator can hit a single identifying key each time that a new speaker or agenda item begins. The system will capture the interval between stroke time and generate statistics concerning how much time was spent on each agenda item and how much time was consumed by each meeting participant. The researchers envision analyses of information derived during the meeting and used to enhance the meeting in real time. Alternative meeting styles and structures are also being explored, and future research may be carried beyond the face-to-face meetings covered in this paper.

Benbasat, Izak and Benn Konsynski, "Introduction to Special Section on GDSS," *MIS Quarterly*, Volume 12, Number 4, December 1988, pp. 588-624.

Organizations are undergoing radical changes in both their use of technology and their basic practices. We can expect that these changes will accelerate as the pressure continues to grow. Managers are faced with radical restructuring initiatives to support the downsizing, downscaling, and delayering of objectives. The growth of interfunctional teams and often cross-organizational teams is leading to further initiatives in the establishment of *groups* and cooperative clusters of both short and long term duration. Integration within and across the organizational boundaries is further stimulating interest in leveraging information technologies to enable and support work of groups and teams. Whether these are teams with a specific mission, standing committees that have a regular or recurring work schedule, or specially assembled groups that will have little cooperation beyond the current task at hand, each has different interests in applying information technologies to support these meetings and other group work.

Bodker, Susanne, Jorgen Lindskov Knudsen, Morten Kyng, Pelle Ehn, and Kim Halskov Madsen, "Computer Support for Cooperative Design," *Association for Computing Machinery*, 1988, pp. 377-394.

Computer support for design as cooperative work is the subject of our discussion in the context of our research program on Computer Support in Cooperative Design and Communication. We outlined our theoretical perspective on design as cooperative work, and we exemplified our approach with reflections from a project on computer support for envisionment in design--the APLEX and its use. We see envisionment facilities as support for both experiments with and communication about the future use situation. As a background, we sketched the historical roots of our program--the Scandinavian collective resource approach to design and use of computer artifacts, and made some critical reflections on the rationality of computer support for cooperative work.

Bui, Tung X. and Matthias Jarke,"Communications Design for Co-Op: A Group Decision Support System," *ACM Transactions on Office Information Systems*, Volume 4, Number 2, April 1986, pp. 81-103.

Decision Support Systems (DSSs), computer-based systems intended to assist managers in preparing and analyzing decisions, have been single-user systems for most of the past decade. Only recently has DSS research begun to study the implications of the fact that most complex managerial decisions involve multiple decision makers and analysts. A number of tools for facilitating group decisions have been proposed under the label Group Decision Support Systems (GDSSs).

One of the most important functions of a GDSS is to provide problem-oriented services for communication among decision makers. On the basis of an analysis of the communication requirements in various group decision settings, this paper presents an architecture for defining and enforcing dynamic application-level protocols that organize decision group interaction. The architecture has been implemented on a network of personal computers in Co-op, a GDSS for cooperative group decision making based on interactive, multiple-criteria decision methods.

Bui, Tung, "Where Are We In Computer Mediated Cooperative Work and GDSS Research?," Department of Administrative Sciences, Naval Postgraduate School, Monterey, CA.

Bui, Tung, Naval Post Graduate School, Monterey, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

Bui, Tung X., Naval Postgraduate School, "NAI: A Concensus Seeking Algorithm for Group Decision Support Systems," *IEEE 1985 Proceedings of the International Conference on Cybernetics and Society*, pp. 380-384.

Bui, Tung (Naval Postgraduate School, Monterey) and Matthias Jarke (New York University), "Communications Requirements for Group Decision Support Systems," *Journal of Management Information Systems*, Volume II, Number 4, Spring 1986.

> Despite the increasing interest in developing group decision support systems (GDSS), it remains unclear how communications between participants of a group problem solving process can be designed, implemented, and utilized in a computer-based distributed GDSS. This paper presents a framework for developing a Communications component for the GDSS. It supports conceptualization of a communication system as being composed of four main modules: the Group Norm Monitor, the Group Norm Filter, the Invocation Mechanism, and the individual decision support system (IDSS)-to GDSS Document Formatter. In reference to the International Standard Organization (ISO) Open System Architecture, the three first modules are integrated in the Application layer, and the last module in the Presentation layer.

Burbridge, John J. and William H. Friedman, "The Integration of Expert Systems in Post-Industrial Organizations," North Holland Human Systems Management 7, 1987, pp. 41-48.

> During the emerging information age, organizations will have to adopt improved decision-group technologies and structures. One such technology will be expert systems. The purpose of this paper is to present a framework to ascertain the applicability of an expert system to a particular decision area. Attributes such as quality of a decision, the structure of a problem and the necessary expertise and information influence this decision. Before this framework is presented, issues concerning the ability of an organization to assimilate such a technology and transfer that technology throughout are discussed. Includes Sprague's prerequisite characteristics for DSS. Defines Communication Systems vs. Information Systems.

Burns, Alan, Margaret. Rathwell, and Richard Thomas, United Kingdom, "A Distributed Decision-Making System," *Decision Support Systems 3*, North-Holland, 1987, pp. 121-131.

> A message based model of a Distributed Decision Making (DDM) system is presented. This model is developed from a survey of the needs of group decision-making processes within organizations and distributed computer applications: a review of this survey is given. DDM extends the DSS concept to one that enables two or more decision making parties to cooperate in using DSS tools. It assumes a framework of organizational decision making which concentrates on the organization as a political system where communication is important and conflict between groups just as likely as consensus. A brief description of a prototype implementation of the model is given. The use of the prototype has upheld the principles from which DDM was designed.

Chase, Sheldon, Jesse H. Wright, and Rammohan Ragade, "Decision Making in an Interdisciplinary Team," *Behavioral Science*, Volume 26, 1981, pp. 206-215.

Decision making in an interdisciplinary team occurs at the interface between groups with varied backgrounds, orientations, interests, and goals. Most interdisciplinary teams attempt to identify the complex set of variables influencing their decisions and then utilize this knowledge to maximize efficiency in health care delivery. Models of information and decision analysis developed by general systems theory (von Bertalanffy) are suggested as a method for advancing the understanding of where, when, and how decisions are made by the interdisciplinary team.

A university-affiliated psychiatric service in a private general hospital is studied. Here the following forces meet, complement, compete, and collide: the community, university, hospital administration, private practitioners, insurance companies, consultation and liaison psychiatrists, university staff psychiatrists and residents, nurses, aides, social workers, activities personnel, patients and their families, the patient group, the ward milieu. Considering these factors, this article describes: (1) the flow of information and feedback loops into, within, and out of the psychiatric service; (2) the location of decision nodes; (3) decision-making echelons. The general systems theory concepts utilized in this analysis are proposed as pragmatic tools for improving interdisciplinary team function.

Christakis, A., and D. Keever, "An Overview of Interactive Management," unpublished document, 1984.

Interactive Management (IM) is a new and versatile style of management which is to be applied intermittently in organizational settings for task-oriented, group problem-solving. IM represents a means of augmenting current management practices when solving complex, interdependent management problems. Experience has shown that these complex problems have failed to yield to conventional solution strategies, including the use of management consultants, organizational development programs, or personnel adjustments. IM has been invented to address these and other shortcomings when solving difficult management problems.

This brief overview of Interactive Management is divided into three sections: The Foundations of Interactive Management; Practicing Interactive Management, and A Typical Life-Cycle of Installing IM in Organizations.

Christakis, Alexander N., "High Technology Participative Design: The Space-Based Laser," Center for Interactive Management, George Mason University, Fairfax, VA.

The arena of high-technology design is inherently complex. It requires a variety of inputs from diverse knowledge disciplines and fields. When a group of experts engages in system design, new problems emerge for the designer(s) of having to cooperate with other designers. Yet, without the simultaneous participation of other designers, the "Law of Requisite Variety" will be violated. Each participant designer is expected to learn to cooperate with other designers and to appreciate the pluralities of realities relevant to the object of design. Yet each designer is physiologically and/or psychologically constrained by the "Law of Requisite Parsimony." These two fundamental laws of design are superficially incompatible or contradictory to each other. For the efficient conduct of participative design, the two laws must be reconciled. The paper discusses how the application of the Interactive Management (IM) approach reconciles this

contradiction. A specific application of IM to the conceptual design of a space-based laser system is presented.

Colab: Toward a Meeting of Minds, *Benchmark*, Fall 1987, pp. 12-14.

Conklin, Jeff and Michael L. Begeman, "gIBIS: A Hypertext Tool for Exploratory Policy Discussion," MCC Software Technology Program, pp. 1-22.

This paper describes an application specific hypertext system designed to facilitate the capture of early design deliberations. It implements a specific method called Issue Based Information Systems (IBIS), which has been developed for use on large, complex design problems. The hypertext system described here, gIBIS (for graphical IBIS) makes use of color and a high speed relational database server to facilitate building and browsing typed IBIS networks. Further, gIBIS is designed to support the collaborative construction of these networks by any number of cooperating team members spread across a local area network. Early experiments suggest that the IBIS method is still incomplete, but there is a good match between the tool and method even in this experimental version.

MCC's experiments with gIBIS are informing their theory about the structure of design decisions and design rationale, and are providing them with important insights about the design of the Design Journal, a hypertext-based environment for system engineering which they will continue to design, prototype, and test in the next few years. More importantly, their experiences suggest that the computer is indeed a powerful medium for collaboration and debate among members of a team, but that the integration of computers into the fine detail of real work is attended by some severe breakdowns. Some of the breakdowns are due to inadequate interfaces, others to inappropriate underlying representations, and still others to insufficiently rich models of work practices and methods. MCC's experience with gIBIS suggests that they are just at the beginning of a long but exciting path, which will culminate when they have succeeded in making such tools as effective and transparent in structuring communication as the telephone has grown to be in simply transmitting it.

Cooke, Robert A. and John A. Kernaghan, "Estimating the Difference Between Group Versus Individual Performance on Problem-Solving Tasks," *Group & Organization Studies*, Volume 12, Number 3, September 1987, pp. 319-342.

An extensive amount of research has focused on the relative performance of groups versus individuals in problem-solving situations. The results of this research have been inconsistent. To some extent these inconsistent findings can be attributed to differences in the variables used to represent individual and group output and the methods employed to compare their performance. This research uses data from 61 groups (347 individuals) who completed a planning simulation to review, compare, and contrast alternative strategies (or "scoring algorithms") for estimating the differences between group versus individual performance on problem-solving tasks. Although the alternative strategies produced different estimates of the amount of gain that can be attributed to group interaction, they generally supported the conclusion that groups outperform their individual members. These results are discussed in terms of research on group performance, the use of simulations for training, and the role of groups in organizational problem solving and task performance. The article includes a discussion of Quality Circles (QC's).

Cooper, Coleen R., Mary L. Ploor, "The Challenges That Make or Break a Group." *Training and Development Journal*, April 1986, pp. 31-33.

As groups work to accomplish goals, they encounter challenge points that must be addressed if participants represent different views, organizations, units in an organization, or economic sectors. This article presents an investigation into what makes a successful group that disclosed at least seven general occasions that provide a challenge for a group leader and participants. It includes a discussion of a strategic planning analysis process called SWOT analysis (internal Strengths and Weaknesses and external Opportunities and Threats).

Cox, Louis Anthony, Jr., "Knowledge-Based Resolution of Conflicting Opinions." *U.S. WEST Advanced Technologies*, Englewood, CO.

If a group of decision makers must jointly choose one of several possible acts and if they disagree about the probable consequence of the acts, then how can they resolve their differences and make a choice? The managerial science literature has offered several probability aggregation formulas for solving this problem. This paper discusses an alternative that emphasizes knowledge-based resolution of conflicting probability judgments.

Davis, Liane and Ronald W. Toseland, "Group Versus Individual Decision Making: An Experimental Analysis," *Social Work with Groups*, Volume 10, Number 2, 1987, pp. 95-110.

Task groups are often used to make decisions in social service agencies. A number of factors influence whether a decision is made by a group or an individual. The nature of the problem, political considerations, and ideology all play a significant role. Sometimes groups are used because of the belief that they make better decisions than can individuals. It is this belief that is the focus of this paper.

Should social workers use groups to make decisions because they are more likely to produce better decisions than individuals working alone? What is the evidence for the superiority of group as compared to individual decision making? In this article the results and methodological limitations of prior studies comparing group to individual decision making are reviewed. Next, the results of an experiment comparing group and individual decision making are described. The research design utilizes a problem that is relevant to social workers and parallels the types of decisions typically made in the profession. The article ends with a discussion of the implications of the findings both for research and for decision making in social service agencies.

Decision Techtronics Group, "Decision Conferences," Rockefeller Institute of Government, Albany, NY.

DeJean, David, "The Electronic Workgroup," *PC/Computing*, October 1988, pp. 72-84.

Workgroup computing--the next logical extension of personal computing--is still an undisciplined discipline. But early reports on some new software programs are encouraging.

Dennis, Alan R., Joey F. George, Len M. Jessup, Jay F. Nunamaker, Jr., and Douglas R. Vogel, University of Arizona, "Information Technology to Support Electronic Meetings," *MIS Quarterly*, Volume 12, Number 4, December 1988, pp. 591-624.

As managers spend more of their time in meetings, the study of information technology to support meetings becomes increasingly important. Several unique systems to support meetings electronically have been developed in industry and universities. The PLEXSYS systems at the University of Arizona have been operational since 1985 and are now being implemented in industrial sites. This article proposes and defines a new term for information technology systems that support group meetings; electronic meeting systems (EMS). EMSs are more than group decision support systems (GDSS): they support more tasks than just decision making; they focus on communication. They move beyond the GDSS decision room, where groups must meet at the same time in the same place, to meetings that can be conducted across time and space. The article then presents a model of the EMS concept, which has three components: group process and outcomes; methods; and environment. Each of these components is explained in turn, and the implications derived from their study to date are discussed. Finally, the implementation of information technology for meeting support and its use in corporate settings will be addressed, as it has implications for productivity, meeting size, group member participation, and the role of the IS department.

DeSanctis, Gerardine and R. Brent Gallupe, University of Minnesota and School of Business, Queen's University, "A Foundation for the Study of Group Decision Support Systems," *Management Science*, Volume 33, Number 5, May 1987, pp. 589-609.

Technical developments in electronic communication, computing, and decision support, coupled with new interest on the part of organizations to improve meeting effectiveness, are spurring research in the area of group decision support systems (GDSS). A GDSS combines communication, computing, and decision support technologies to facilitate formulation and solution of unstructured problems by a group of people. This paper presents a conceptual overview of GDSS based on an information-exchange perspective of decision making. Three levels of systems are described, representing varying degrees of intervention into the decision process. Research on GDSS is conceived as evolving over time from the study of simple "shell" systems, consisting of menus of features available for selection by a group, to consideration of sophisticated rule-based systems that enable a group to pursue highly structured and novel work for research in the area. Three environmental contingencies are identified as critical to GDSS design: group size, member proximity, and the task confronting the group. Potential impacts of GDSS on group processes and outcomes are discussed, and important constructs in need of study are identified.

Tables of problems/needs and features for Levels 1, 2, and 3 GDSS, and a table of GDSS features for six task types are included in the article.

DeSanctis, Gerardine, V. Sambamurthy and Richard T. Watson, "Building a Software Environment for GDSS Research," *DSS-88 Transactions*, Eighth International Conference on Decision Support Systems, Boston, MA, 1988, pp 3-12.

This paper describes a Unix-based, multi-user, conference-room system that has been developed to support a research project concerned with the impacts of group decision support systems on the processes and outcomes of group meetings. The systems development effort of this project is given

as an example of one approach to implementing GDSS in a research setting. It is not argued that this approach should necessarily be used in all GDSS settings. The architecture and logical design of the system is presented, and the major features of the system are described. A key aspect of this system is its ability to allow the researcher to determine the types and sequencing of features that are made available to a group in the course of their meeting. The evolution of the system is described, along with a plan for evaluating the system and its impacts.

The system building effort described in this paper does not solve the problem of incompatibility across conferencing systems, nor does it move products in this area toward standardization. Rather, the project described here--and others like it--can be regarded as precursors to achieving standardization among face-to-face conferencing systems. Experimentation with alternative GDSS architectures, accompanied by a systematic evaluation of the technical performance, interface quality, and user and group impacts of these systems, can provide the knowledge necessary to advance the development and study of support systems for groups.

Dierolf, David A., Institute for Defense Analyses, Alexandria, VA, viewgraphs, *Research in Computer-Supported Meetings*, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

Eck, R., M. Goul, A. Phillippakis, and S. Richards, "Group Operating Systems for Decision Factories of the Future: An Extended Relational GDSS Architecture," Department of Decision and Information Systems, University of Arizona.

This work focuses on technological issues for a unifying GDSS architecture. A relational GDSS architecture employing extended data base concepts and and an associated processing kernel or *GDSS Operating System (GOS)* are set forth. The proposed architecture is sufficiently robust to represent existing and anticipated group decision support systems. Major benefits include: (1) System configuration, session control, group work products, and research variable settings are stored in and can be retrieved from a common data base; (2) a GOS is recognized to be a query processor employed to define, control, and coordinate group sessions; (3) The relational structure supports distributed implementations; and (4) The architecture is consistent with research proposing the integration of data, models, and solvers for decision applications.

Einhorn, Hillel and Robin M. Hogarth, University of Chicago, "Decision Making: Going Forward in Reverse," *Harvard Business Review*, January-February 1987, pp. 66-70.

Foote, Cornelius F., Jr., "Designing Tomorrow's Community in a Week," *The Washington Post*, 11 June 1988.

After a high-speed planning session, a town takes shape.

Foster, Gregg and Mark Stefik, "Cognoter, Theory and Practice of a Colab-Orative Tool," *Proceedings of Conference on Computer-Supported Cooperative Work*, 3-5 December 1986, pp. 7-15.

Cognoter is a program that helps a cooperative group of people to organize their thoughts for a presentation, e.g., a paper or talk. It is designed for use in the Colab, an experimental laboratory created at Xerox PARC to study computer support of cooperative real-time group problem-solving. Cognoter provides a multi-user interface and a structured meeting process. An annotated graph of ideas is built up by the group in three stages:

brainstorming for idea generation, ordering for idea organization, and evaluation for choosing what will be finally be presented. Interesting aspects of Cognoter include direct spatial manipulation of ideas and their order relationships, support of parallel activity, and incremental progress toward a total ordering of ideas.

Gallupe, R. Brent, Gerardine DeSanctis, Gary W. Dickson, "The Impact of Computer-Based Support on the Process and Outcomes of Group Decision Making," *Proceedings of the Seventh International Conference on Information Systems*, San Diego, CA, 15-17 December 1986, pp. 81-83.

> Interactive computer-based systems to support group decision making (group decision support systems or GDSS) have received increased attention from researchers and practitioners in recent years. Huber (1984) argues that as organizational environments become more turbulent and complex, decisions will be required to be made in less time and with greater information exchange within decision making groups. Thus, it is imperative that studies be undertaken to determine the types and characteristics of group decision tasks most appropriate for support by a GDSS and to determine the features of a GDSS that will support those tasks.
>
> A number of prominent researchers in the field of group decision making agree that the decision task itself is probably the most important factor in determining group decision making effectiveness. The characteristics of group decision tasks are many and varied, but the level of difficulty/complexity of the decision is a fundamental factor in influencing the performance of the group. Some decisions are characterized by information that is clear, concise, easily communicable, and where relationships between important factors in the decision are easily understood. In short, these decisions require relatively little effort to make and are therefore called easy decisions. Decision tasks where the information to be considered in making the decision is incomplete, difficult to understand, and where complex relationships exist within the information available are called complex or difficult decisions. The role of decision task difficulty in the effective use of GDSS is considered in this study.
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> This paper includes measures of effectiveness of GDSS's in terms of decision outcomes and decision process variables.

Gallupe, R. Brent (School of Business Queen's University), Gerardine DeSanctis, and Gary W. Dickson (University of Minnesota), "Computer-Based Support for Group Problem-Finding: An Experimental Investigation," *MIS Quarterly*, June 1988, pp. 277-296.

> There is very little empirical research available on the effectiveness of decision support systems applied to decision-making groups operating in face-to-face meetings. In order to expand research in this area, a laboratory study was undertaken to examine the effects of group decision support systems (GDSS) technology on group decision quality and individual perceptions within a problem-finding context. A crisis management task served as the decision-making context. Two versions of the experimental task, one higher in difficulty and the other lower in difficulty, were administered to GDSS-supported and nonsupported decision-making groups, yielding a 2 x 2 factorial design. Decision quality was significantly better in those groups that received GDSS support. The GDSS was particularly helpful in the groups receiving the task of higher difficulty.

Members' decision confidence and satisfaction with the decision process were, however, lower in the GDSS-supported groups than in the nonsupported groups. These findings expand knowledge of the applicability of GDSS for decision-making tasks and suggest that dissatisfaction may be a stumbling block in user acceptance of these systems.

Gallupe, R. Brent, Lakehead University, Canada, "Experimental Research into Group Decision Support Systems: Practical Issues and Problems," *Proceedings of the Nineteenth Annual Hawaii International Conference on System Sciences*, Volume 1A: Architecture, Decision Support Systems and Knowledge-Based Systems, Special Topics, 1986, pp. 515-523.

Interactive computer-based systems to support group decision making (GDSS) have received increased attention from researchers and practitioners over the past three or four years. Huber (13) argues that as organizational environments become more turbulent and complex, decisions will be required to be made in less time, and with greater information exchange within decision making groups. Thus, it is imperative that studies be undertaken to determine the types of group decision tasks most appropriate for support by a GDSS, and to determine the features of a GDSS that will support those tasks. This paper examines some of the issues that must be addressed by researchers conducting experimental studies in GDSS. If the results of these experimental studies are to mean anything in *real* group decision situations then these issues must be considered and dealt with.

The specific issues examined in this paper are: (1) the group decision task; (2) the group decision support system; (3) the subjects and setting used in GDSS experiments; and (4) the measures of decision outcomes and processes. These issues are examined from a practical rather than theoretical point-of-view. This paper is based on a recent experiment into GDSS. The experiment and the preliminary results of the experiment are described in terms of these four issues. Finally, recommendations for the resolution of the issues are proposed.

Gantt, Jim, U.S. Army Institute for Research in Management, Information, Communications, and Computer Science, Georgia Institute of Technology, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

George, Joey F., J. F. Nunamaker, Jr., and Douglas R. Vogel, "Group Decision Support Systems and Their Implications for Designers and Managers: The Arizona Experience," *DSS-88 Transactions*, Eighth International Conference on Decision Support Systems, Boston, MA, 1988, pp. 1325.

The Department of Management Information Systems at the University of Arizona has a long history concerning group decision support systems (GDSS). This history began with the development of PLEXSYS, a system development system, and with work on integrated development environments for information systems. To date, Arizona has developed two separate GDSS facilities. Both support not only group decision making but also group deliberation and negotiation. The University of Arizona PlexCenter facility has been operational since March 1985, with state of the art computer hardware and software used in a boardroom setting. Executives, managers, and professional staff from organizations use the facility for organizational planning and to address complex, unstructured decision problems. The facility has received considerable national and international attention.

The GDSS work done at the University of Arizona has helped establish the baselines for what is essential for successful GDSS use by real world groups, the groups for which GDSS are designed. Controlled experiments, currently in progress, are beginning to confirm much of the information already gathered through GDSS use and observation. Designers of GDSS and managers who use technology can both benefit from GDSS research that has been conducted at Arizona and elsewhere.

In many ways GDSS are in their infancy. There is still much to learn. One observation is that, to date, all that has been done is to use GDSS to mimic processes that are already done manually. Yet this is not the true strength or promise of such systems. To tap into the true potential of GDSS, researchers need to go beyond imitation to those things that can be done only with the use of this new, and as yet incompletely explored, technology.

George, Mary, Decision Analysis Center, Headquarters, Department of the Army, Pentagon, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

Gerstein, Marc S., "Computer-Aided Meetings."

The Mac's role in meetings can go way beyond desktop presentations. By augmenting the meeting process itself, you can increase work group productivity many times.

Gibson, David V. and E. Jean Ludll, "Executive Group Decision Support Systems Considered at Three Levels of Analysis," *DSS-88 Transactions*, Eighth International Conference on Decision Support Systems, Boston, MA, 1988, pp. 26-38.

This research is based on a case study of the implementation, use and eventual demise of an executive level group decision support system (GDSS). Key issues discussed which are considered generalizable to all GDSS's concern (1) executives as secretive, intuitive information processors, (2) a critique of open communication across organizational hierarchies and functions, and (3) the symbolic value of a GDSS to an organization's internal and external environments. Different levels of analysis emphasize the importance of considering group, organizational, and environment contexts when evaluating the effectiveness of a GDSS.

Gray, Paul, "Group Decision Support Systems," *Decision Support Systems*, Volume 3, Number 3, September 1987, pp. 233-242.

Group Decision Support Systems (GDSS) has been a rapidly emerging field of the 1980's. Whereas conventional Decision Support Systems (DSS) help individual decisions makers, GDSS are designed to help groups of senior management and professional groups reach concensus. The paper focuses on one type of GDSS, a decision room in which computers and communications are used by participants during their deliberations. The paper introduces the concepts of private work, public screen, and chauffeur. It then discusses how software and hardware are used in current GDSS. Practical experience has mostly been in laboratory setting. The paper describes existing facilities and reports on the experimental evidence thus far. Special attention is given to the potentials of using gaming and the opportunity for research replication. Although it is not yet possible to prove that GDSS will be viable in the long-term, some potential directions of change can be anticipated if GDSS proves successful. Contains listings of example GDSS's and research issues and a chart of variables in the study of GDS.

Gray, Paul, "The User Interface in Group Decision Support Systems," *DSS-88 Transactions*, Eighth International Conference on Decision Support Systems, Boston, MA, 1988, pp. 203-225.

The human interface is a critical success factor for group decision support systems (GDSS). This paper describes and illustrates the interfaces used in four experimental GDSS's (University of Arizona, Claremont Graduate School, University of Minnesota, and XEROX PARC). These systems are all of the single room type, where participants are present at the same time. The design problem for such systems is more complex than that for individual work stations because it involves not only consideration of both the public and private screens, but also of the interaction between these screens, the physical environment of the facility, the response time of the network, and cognitive style. The interfaces described ranged in approach from simple listings, to conventional microcomputer interface, to near typewriterless interfaces using touchscreens, to a highly sophisticated "what you see is what I see" (WYSIWIS).

Following a description of the current systems, four interface design issues specific to decision support for groups are discussed: the design of the public screen, the interaction between the private screens and the public screens, the design of the individual's interaction with the system as a whole, and the effects of varying cognitive style and cultural differences among participants.

Gray, Paul and Lorne Olfman (Claremont Graduate School), "The User Interface in Group Decision Support Systems," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 119-137.

Same as above.

Group Support Technologies, a study prepared for Organizational Planning and Development Division, Office of Human Research Development, Human Resource Management, Federal Aviation Administration (FAA), Unisys Corporation, January 1990.

Grudin, Jonathan, MCC, "Why CSCW Applications Fail: Problems in the Design and Evaluation of Organizational Interfaces," *Association for Computing Machinery*, 1988, pp. 85-93.

Many systems, applications, and features that support cooperative work share two characteristics: A significant investment has been made in their development, and their successes have consistently fallen far short of expectations. Examination of several application areas reveals a common dynamic: (1) A factor contributing to the application's failure is the disparity between those who will benefit from an application and those who must do additional work to support it; (2) A factor contributing to the decision-making failure that leads to ill-fated development efforts is the unique lack of management intuition for Computer-Supported Cooperative Work (CSCW) applications; and (3) A factor contributing to the failure to learn from experience is the extreme difficulty of evaluating these applications. These three problem areas escape adequate notice due to two natural but ultimately misleading analogies: the analogy between multi-user application programs and multi-user computer systems, and the analogy between multi-user applications and single-user applications. These analogies influence the way we think about cooperative work applications and designers and decision-makers fail to recognize their limits. Several CSCW application areas are examined in some detail.

Hardaker, Maurine and Bryan K. Ward, "Getting Things Done, How to Make a Team Work," *Harvard Business Review*, November-December 1987, pp. 112-117.

Anyone who has ever run a business or organized a project has discovered how hard it can be to get the whole team on board to ensure that everyone knows where the enterprise is heading and agrees on what it will take to succeed.

IBM has used a method for some years that helps managers do just this. The technique, which is called PQM or Process Quality Management, grew out of many studies with customers to determine their needs and from internal studies as part of IBM's business quality program. PQM has been used successfully by service companies, government agencies, and nonprofit organizations, as well as manufacturers.

Harker, P.T., "Incomplete Pairwise Comparisons in the Analytic Hierarchy Process," *Mathematical Modeling*, Volume 9, Number 11, 1987, pp. 837-848.

The Analytic Hierarchy Process is a decision-analysis tool which was developed by T.L. Saaty in the 1970s and which has been applied to different decision problems in corporate, governmental and other international settings. The most successful applications have come about in group decision-making sessions, where the group structures the problem in a hierarchical framework and pairwise comparisons are elicited from the group for each level of the hierarchy. However, the number of pairwise comparison necessary in a real problem often becomes overwhelming. For example, with 9 alternatives and 5 criteria, the group must answer 190 questions. This paper explores various methods for reducing the complexity of the preference eliciting process. The theory of a method based upon the graph-theoretic structure of the pairwise comparison matrix and the gradient of the right Perron vector is developed, and simulations of a series of random matrices are used to illustrate the properties of this approach.

Hill, Ray, Air Force Human Resources Laboratory, Wright-Patterson AFB, *Group Decision Support*, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

Hiltz, Starr Roxanne, Murray Turoff (New Jersey Institute of Technology), and Kenneth Johnson (Upsala College), "Experiments in Group Decision Making, 3: Disinhibition, Deindividuation, and Group Process in Pen Name and Real Name Computer Conferences," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 217-232.

This field experiment focused on the effect of using pen names (a form of anonymity) in computer conferences for group decision making in choice dilemma tasks. The subjects were peer groups of managers in a large, conservative corporation with a well developed *corporate culture*. It was hypothesized that pen name conferences might exhibit more distributed and deindividuated behavior than conferences in which comments were signed with the real name of the contributor. There was actually little disinhibited behavior in either mode of computerized conferencing. Pen name conferences showed consistent but statistically insignificant tendencies

toward less disagreement about the final group choice, more participation, and greater equality of participation. The final group choices are significantly more conservative in pen name computer conferences within this conservative subculture. This may be interpreted as providing support for the hypothesis that there is more deindividuation in the pen name condition. In sum, problem-solving techniques using software structures that employ forms of anonymity appear to be helpful options in future group decision support systems built within computer-mediated communication systems.

Huber, George P., "Issues in the Design of Group Decision Support Systems," *MIS Quarterly*, September 1984, pp. 195-204.

This paper deals with a number of issues pertinent to the design of group decision support systems. It notes that the need for such systems, whether designed by users or vendors, is a consequence of the clash of two important forces: (1) the environmentally-imposed demand for more information sharing in organizations, and (2) the resistance to allocating more managerial and professional time to attending meetings. The paper focuses on three major issues in the design of these systems: (1) system capabilities, (2) system delivery modes, and (3) system design strategies, and discusses the relationship of these issues to system use and survival. The relevance of numeric information, textual information, and relational information in a decision-group context are examined, and various system capabilities for displaying and using such information area noted.

Huber, George P. and Reuben R. McDaniel, "The Decision-Making Paradigm of Organizational Design," *Management Science*, Volume 32, Number 5, May 1986, pp. 572-589.

This paper introduces and explicates the decision-making paradigm of organizational design. We argue that the domains of existing design paradigms are declining in scope, and that the nature of current and future organizational environments requires use of a design paradigm that responds to the increasing frequency and criticality of the decision-making process. In particular, we argue that the decision-making paradigm is applicable when the organizational environments are hostile, complex, and turbulent.

The focal concept of the decision-making paradigm is that organizations should be designed primarily to facilitate the making of organizational decisions. The paper sets forth the paradigm's six major concepts and discusses the principal domains of its application. The paper also examines the relationships between the decision-making paradigm and the literatures on (1) organizational decision making, (2) the information processing view of organizations, and (3) the need for compatibility between the organization's design and the design of its technologically supported information systems. The paper concludes by identifying ten organizational design guidelines that follow from the decision-making paradigm.

Huber, George P., *Group Decision Support Systems as Aids in the Use of Structured Group Management Techniques*, University of Wisconsin-Madison, 1982.

Structured group management techniques such as the Nominal Group Technique, the Delphi Technique, Social Judgment Analysis, and Potential Problem Analysis have been shown through both experience and scientific studies to be superior to less structured processes for helping groups make decisions, at least in some situations. Nevertheless, even though these techniques are, overall, quite beneficial in their present form, each contains component processes that are procedurally cumbersome and aggravatingly inefficient. This is especially true of those processes involving information aggregation, analysis, or display.

GDSS, such as those described in the paper, have features that seem well suited to reducing the inefficiencies associated with structured group management techniques. This paper briefly outlines the component processes of the Nominal Group Technique and the Delphi Technique, identifies in each technique the component processes that are most troublesome, and shows how Group DSS can be used to reduce the inefficiencies associated with these components and in this way, enhance the overall effectiveness of the techniques themselves. The paper then examines the issue of the domains in which GDSS might be appropriate and suggests research efforts that might help to determine the boundaries of these domains.

Human Factors Guidelines for the Design of Computer-Based Systems, Part 2, Issue 1, Project Initiation, Ministry of Defence (Procurement Executive), Department of Trade and Industry, London, 1988.

Humphreys, Patrick, "Intelligence in Decision Support," *New Directions in Research on Decision Making*, B. Brehmer, H. Jungermann, P. Lourens, and G. Sevon (Editors), Elsevier Science Publishers, B.V. (North-Holland), 1986, pp. 333-361.

This paper focuses on methods for handling problems set in organizational contexts where, at the outset, there is considerable uncertainty about what is involved in handling the problem. Somewhere, within the organization, there should be considerable "intelligence" available in the form of knowledge about the nature of the organization, the genesis of the problem, and possible consequences of decisions taken in the attempt to alleviate or resolve the problem. The question then becomes how to harness this intelligence in a constructure way providing appr[illegible]riate decision support to particular people (or groups of people) involv[illegible] the problem handling process.

Humphreys, Patrick, "Levels of Representation in Structuring Decision Problems," *Journal of Applied Systems Analysis*, Volume 11, 1984, pp. 3-22.

This paper is one of three in this volume which aim to provide a basis for developing an adequate methodology for the design, development and implementation of decision aiding systems for structuring ill-defined decision problems. The other two papers are "Psychological Validation of Decision Methods," by O.I. Larichev, and "Selecting Decision Support Methods in Organisations," by A. Vari and J. Vecsenyi.

An *ill-defined* problem is our term for a problem where at the outset there is considerable uncertainty about what is involved in the problem and how to represent it. This type of problem--usual in real life--tends to be glossed over in accounts of decision theory and decision analysis, where the structure of the problem is either given in a description that was constructed *a priori*, or magically appears as part of the decision maker's--or analyst's--practice.

This paper examines issues involved in supporting decision making in unique rather than repeated situations, where the decision maker cannot make the decision on the basis of holistic choice between alternatives about which he has complete information-gestalten. Cases where the decision maker is the problem owner but who on his own has insufficient information to formulate and implement a policy for action are the focus.

Humphrey, P.C., A.I. Oldfield and J. Allan, *Intuitive Handling of Decision Problems: A Five-Level Empirical Analysis*, Technical Report 87-3, The London School of Economics and Political Science.

The research reported in this report posits and tests a theory that people's intuitive handling of unstructured decision problems (that is, those problems in which neither the environment nor convention nor habit dictate an appropriate solution) consists in five levels of subjective, psychological problem structuring. The key features of these five decision making levels are:

(1) What is qualitatively different at each decision making level are the operations carried out in forming judgments about how the problem is to be handled and solved

(2) The results of the operations carried out on a particular level constrain the ways operations are carried out at all lower levels

(3) Any decision problem is potentially represented "in the real world" at all levels. Therefore, levels cannot be treated like a taxonomy for classifying decision problems; instead, the handling of problems at each decision making level has to be examined.

In the study reported, four of these five decision making levels were manipulated under four different experimental conditions. Within these conditions, subjects' discussions of a topic having significant real-life impact for them (local hazardous waste disposal) were constrained in one of four ways by interviewer-imposed constraints, each constraint corresponding to one of the posited decision making levels.

A major empirical question addressed in this report is the extent to which intuitive decision making is impaired or facilitated by setting constraints externally, as terms of reference or as an initial problem statement, at a particular decision making level. No previous empirical research on judgment and decision making has dealt with this problem. The posited five decision making levels provided not only the rationale for the experimental design but also different ways of analyzing transcripts of subjects verbal handling of the problem. These analyses led to the following conclusions:

1. Imposing the minimum constraint of only specifying the problem area asks too much of people; their exploration of the problem is very limited. To help them get started in their thinking, priming them with either a bounded scenario or a frame within which to represent the problem proved very successful.

2. The main tradeoff in practice has to be made between priming subjects with scenarios (level 4) or frames (level 3). Priming with a frame within which to represent the problem tended to encourage more "depth" (structuring within the offered frame). Priming within a scenario encouraged more "breadth" (exploring across intuitively selected frames). In each case, though, subjects still explored more beyond the areas in which they were primed than within the areas in which they were primed.

3. Constraining subjects by giving them a fully-structured problem frame (level 2), typical of psychological experiments on judgment under certainty, is counter-productive. Subjects became frustrated and apathetic: they explored less, both within and outside the frame in which they were primed, and this was not compensated for by encouraging them to give more judgments within the frame. In other words, constraining people at this level clearly underestimates their intellectual abilities, and they respond by failing to display much of what they are capable of at any level. Thus, the conclusion made by many judgment researchers, that people are "intellectual cripples" when dealing with uncertainty, may be an artifact of the experimental constraints imposed on subjects.

4. Overall, this research shows the impossibility of maintaining an objective stance on the part of the experimenter in judgment research. The act of stating the problem and what is required of the subject has a profound effect, well beyond the error variance associated with experimenter-induced biases, on the way subjects think about the problem. In addition, the approach used by the experimenter in analyzing the data imposes its own constraints on the conclusions that are drawn. Thus, judgment researchers will need to consider new paradigms that recognize the inseparability of experimenter and subject in investigations of problem-solving for ill-structured situations.

Humphreys, P.C. and A.D. Wisudha, *Handling Decision Problems: A Structuring Language and Interactive Modules, Second Year Annual Report, Part I: Building a Decision Problem Structuring Library: A Review of Some Possibilities*, Technical Report 88-1, Decision Analysis Unit, London School of Economics and Political Science.

This report represents an extension to, and update of, Technical Report 87-1: Methods and Tools for Structuring and Analysing Decisions Problems: A Review and Catalogue (part of the first-year technical report on this project). It examines in detail the four classes of systems and tools for decision support which need to be provided within our General Procedural Schema for handling ill-structured decision problems in order to provide a comprehensive library of microcomputer-based tools to aid the handling of such problems at strategic and lower levels. (Involvement of problem owners at a strategic level is invariably necessary where the decision problem is initially unstructured, and therefore may have new policy implications with the organisation.)

Within each of the four categories, we have selected microcomputer-based support systems and tools from the entries in the catalogue given in Technical Report 87-1 which have a proven track record in use in decision making at the strategic level and at lower levels. We describe their capabilities and limitations against the support goals identified for tools in each particular category within the account of the general procedural schema. The tools selected within each category are not evaluated in competition with each other. Rather, we have assembled a set of tools which, taken together, indicate the state-of-the-art across the full range of support functions which could be offered by technology successfully incorporated in current tools.

This allows us to evaluate the capabilities of the tool set, taken as a whole, and also to consider the ease, or difficulty, of integrating information and methods across tools in the case where comprehensive support for an application may best be provided through the use of functions contained in more than one tool.

In fact, this is the most pessimistic part of our report. It shows that the tools we have selected all have excellent *local* functionality: that is, they are all good at what they profess to do when used to provide practical, but restricted, support on their own. However, global functionality of the set, taken as a whole, is much more difficult to achieve simply through aggregating tools bottom-up into a comprehensive tool set to comprise the library. This is because, even when choosing the members of this set very carefully, as we did in the research which led to this report one always ends up with interfacing and functional coverage problems.

It is not easy to transfer information between tools because object and parameter conceptualisations are not consistent across tools (it is not just a matter of incompatible data formats). Also, the support functions provided overlap between the tools (which offers redundancy, which in itself is not necessarily a bad thing) and, more seriously, leave gaps in functionality between the tools which are not easy to solve through constructing "bolt-on" software, or through decision analyst intervention in practical applications.

We conclude that the next step should be to take a top-down view of what is required in building a decision problem structuring library, deriving first of all the set of support functions, and then describing how they may be clustered into "super-tools" which comprise both functions successfully implemented in existing tools and the required but currently mission functions. Such supertools should not be defined in a closed way. The aim should be to allow any individual library builder to integrate the tools and tool functions he wishes to use (regardless of the source from which they were acquired) into his own comprehensive library, offering *integrated* support facilities, tailored according to the applications needs of the library users.

Humphreys, Patrick C. and Ayleen D. Wisudha, *Methods and Tools for Structuring and Analysing Decision Problems, Volume 1: A Review*, Technical Report 87-1, London School of Economics and Political Science, pp. 1-23 with Appendix.

Humphreys, Patrick C. and Ayleen D. Wisudha, *Methods and Tools for Structuring and Analysing Decision Problems, Volume 2: A Catalogue*, Technical Report 87-1, London School of Economics and Political Science.

This report comprises a review (Volume 1), and catalogue (Volume 2) of 58 methods and tools for structuring and analysing decision problems within a framework for effective organizational problem handling and decision making in initially unstructured situations (i.e., in newly occurring, non-repeating situations, where the structure of the problems is, of necessity, initially unclear).

Huseman, Richard C. (University of Georgia) and Edward W. Miles (Clemson University), *Organizational Communication in the Information Age: Implications of Computer-Based Systems*, Journal of Management, Volume 14, Number 2, 1988, pp. 181-204.

In the information age, the use of computer technology has and will increasingly change the way communications occurs in organizations. In this article, we set forth an Integrative Model of Information Systems and Organizational Communication. Based on this model, we discuss the

communication implications of four computer-based systems: (a) Electronic Messaging Systems (EMS); (b) Executive Information Systems (EIS); (c) Group Decision Support Systems (GDSS); and (d) Executive Presentation Systems (EPS). The major purpose of this article is to provide an overview of these systems and, through a series of propositions, to examine the potential impact of these computerized systems upon the traditional areas of organizational communication.

Hsu, Spencer, "Making Meetings More Meaningful," The Workplace (column), *The Washington Post*, 1 July 1990, p. H-3.

Information Technology and Organizations, National Science Foundation, Fiscal Year 1988 Research Projects.

Jarvenpaa, Sirkka L., V. Srinivasan Rao, and George P. Huber, University of Texas at Austin, "Computer Support for Meetings of Groups on Unstructured Problems: A Field Experiment," *MIS Quarterly*, Volume 12, Number 4, December 1988, pp. 645-666.

This preliminary study was conducted to learn about the consequences of computer support for teams working on unstructured, high-level conceptual software design problems in face-to-face group settings. A networked workstation technology and electronic blackboard technology were contrasted with their conventional counterparts. Twenty-one software designers, assigned to three teams, performed team tasks that involved generating ideas and reaching consensus. Positive effects on the thoroughness of information exchange and quality of team performance were found in the meetings in which electronic blackboard technology was available. The networked workstations provided mixed results. Significant team differences were found in performance and interaction measures. The results and their implications are discussed in terms of the necessary future developments and nature of future research in computer-based meeting support technology.

Jelassi, M. Tawfik (INSEAD, France) and Abbas Forough (Indiana University), "Negotiation Support Systems: An Overview of Design Issues and Existing Software," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 167-181.

Negotiation Support Systems (NSS) are a special class of Group Decision Support Systems which emphasize computerized assistance for situations in which there is strong disagreement on factual or value judgments among group members. This paper first discusses negotiation structuring issues that should be taken into account when designing NSS. These issues include behavioral characteristics and cognitive perspectives of negotiators, communication needs of different bargaining settings, determination of each party's real interest(s), generation of options for mutual gain, and data accuracy and consistency. The paper then reviews negotiation theories used as the basis for designing NSS and provides a comprehensive survey of existing software in the area of computer-support negotiation.

Jelassi, M. Tawfik (Indiana University) and Renee A. Beauclair (University of Louisville), "An Integrated Framework for Group Decision Support Systems Design," *Information and Management*, Volume 13, North-Holland, September 1987, pp. 143-153.

Proposed approaches for the development of Group Decision Support Systems (GDSS) address behavioral and technical aspects of these systems. However, these approaches generally address only one of these aspects at a time. This paper reviews these approaches and suggests a framework for developing GDSS based on an integrated perspective. This proposed framework is comprehensive and integrative as it combines the behavioral characteristics of group decision making with the technical specifications that drive GDSS. Software design and future research issues are discussed.

Keever, D.B. and A.N. Christakis, *Interactive Management for Organizational Redesign*, Center for Interactive Management, George Mason University, Fairfax, VA, pp. 83-90.

Interactive Management (IM) was selected by a U.S. government agency's top manager to assist his line and staff executives in collectively redesigning their organization for the 1990's. Some distinctive aspects of the Interactive Management system, especially useful for organizational redesign, include: computer assistance for exploring the interrelationships among a large number of ideas; a specially-designed situation room; selected methodologies offering neutral, yet firm and flexible guidance for design; and a clear delineation of roles between participants, as content experts, and the group manger (called the IM Facilitator), as process expert.

This paper discusses how the senior managers were successful in identifying anticipated problems for the agency of the 1990's and in proposing a set of viable options for ameliorating the situation. The options were organized in an "Options Field" relevant for designing the organization of the future. The Options Field enables the managers to make strategic choices among the options in a methodical and meaningful manner.

Kersten, Gregory E., "On Two Roles Decision Support Systems Can Play in Negotiations," *Information Processing & Management*, Volume. 23, No. 6, 16 January 1987, pp. 605-614.

This paper focuses on the role of the computer system in group decision-making. Two systems used in solving negotiating problems and three procedures which can be utilized to develop group decision support systems are analysed and a unified approach for the analysis is presented. The systems and procedures are based on multicriteria decision analysis and use mathematical programming models. They can play different roles: (1) systems' intervention in the negotiating process can be used merely to facilitate the process, or (2) the system can actively mediate negotiations; both roles are discussed in this article.

Kersten, Gregory E., "Two Aspects of Group Decision Support System Design," *Proceedings of the VIIth International Conference on Multiple Criteria Decision Making--Toward Interactive and Intelligent Decision Support Systems*, 18-22 August 1986, pp. 283-292.

Two aspects of designing a computer-based system for group decision making are discussed in this paper. The first is the procedure a system uses, which should be able to handle different decision problems and which should support decision-makers who represent different types of behavior. The second aspect is the user-system interface; it should possess features which increase system flexibility and expandability, and it should make possible the customization of the system.

Kersten, Gregory, "NEGO-Group Decision Support System," *Information and Management 8*, 1985, pp. 237-246.

There are two major frameworks for decision making: maximizing and satisficing. A combination of both may be used to describe group decision making (GDM). In the satisficing approach, decision makers (DMs)

formulate aspiration levels or *demands* which take the form of constraints. Choosing from among different decisions, DMs take into account their preference or wants, which take the form of objective functions.

GDM is divided into two stages: first, each DM makes a decision, and second, DMs negotiate so as to achieve a compromise decision. Negotiating is an iterative process. Negotiations are completed when all demands have been met.

The group decision support system *NEGO* assists DMs in finding a compromise. It has been used for solving a GDM problem at the corporate level and is currently utilized in management courses.

Korhonen, Pekka, Herbert Moskowitz, Jyrki Wallenius, and Stanley Zionts, "An Interactive Approach to Multiple Criteria Optimization with Multiple Decision-Makers," *Naval Research Logistics Quarterly*, Vol. 33, 1986, pp. 589-602.

In this article a formal man-machine interactive approach to multiple criteria optimization with multiple decision makers is proposed. The approach is based on some earlier research findings in multiple criteria decision making. A discrete decision space is assumed. The same framework may readily be used for multiple criteria mathematical programming problems. To test the approach two experiments were conducted using undergraduate Business School students as subjects in Finland and in the United States. The context was, respectively, a high-level Finnish labor-management problem and the management-union collective bargaining game developed at the Krannert Graduate School of Management, Purdue University. The results of the experiments indicate that the presented approach is a potentially useful decision aid for group decision-making and collective bargaining problems.

Kraemer, Kenneth and John King, "Computer-Based Systems for Cooperative Work and Group Decision Making: Status of Use and Problems in Development, *Public Policy Research Organization*, University of California, Irvine, CA, September 1986, pp 1-37.

Application of computer and information technology to cooperative work and group decision-making has grown out of three traditions: computer-based communications, computer-based information service provision, and computer-based decision support. This paper provides an overview of the various kinds of systems that have been configured to meet the needs of groups at work, evaluates the status of these systems in the United States, evaluates the experience with them, assesses barriers to their further development and use, and draws conclusions about future work in this area that should be undertaken. An extensive set of references is provided.

Kraemer, Kenneth L.and John Leslie King, University of California, "Computer-Based Systems for Cooperative Work and Group Decision Making," *ACM Computing Surveys*, Volume 20, Number 2, June 1988, pp. 115-146.

Application of computer and information technology to cooperative work and group decision-making has grown out of three traditions: computer-based communications, computer-based information service provision, and computer-based decision support. This paper reviews the group decision support systems (GDSSs) that have been configured to meet the needs of groups at work, and evaluates the experience to date with such systems. Progress with GDSSs has proved to be slower than originally anticipated because of shortcomings with available technology, poor integration of the various components of the computing *package*, and incomplete understanding of the nature of group decision making. Nevertheless, the

field shows considerable promise with respect to the creation of tools to aid in group decision making and the development of sophisticated means of studying the dynamics of decision making in groups.

Krasner, Herb, "Computer-Supported Cooperative Work '86 Conference Summary Report," *AI Magazine*, Fall 1987, pp. 87-88.

This article is the conference chairman's report on the results of CSCW '86. The report introduces the field of computer-supported cooperative work, describes the CSCW '86 program. and discusses the significance of the conference results. An introduction to the follow-on conference, CSCW '88, is also provided.

Kull, David J., "Group Decisions: Can Computers Help?," *Computer Decisions*, May 1982, pp. 70-160.

This paper documents a simulated board of directors meeting using Mindsight, a trailblazer in decision support systems, developed by Execucon (Austin, TX). Contains useful comments from the "board" members.

Lewis, Howard and George Desharnais, Internal Revenue Service, New York, *IRS/NTEU Manhattan District Group Decision Support System*, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

Lewis, L. Floyd, Western Washington University, Bellingham, WA., "A Decision Support System for Face-to-Face Groups," *Journal of Information Science*, Volume 13, February 1987, pp. 211-219.

Several recent trends have converged to make the concept of GDSS important at this time. This paper describes the design, development, and testing of one GDSS tool as an initial step toward building a comprehensive system. A network of microcomputers was used to implement this tool, then the author studied its use by a large number of groups in a controlled laboratory setting. The GDSS proved to have some beneficial impacts on the group process as well as on the final product (decision) for the groups using the computers, as compared to groups using a booklet, or groups with no help. Suggestions for future experimental investigations are offered, as well as potential techniques for improving and expanding the GDSS.

Lewis, Roger K., "When Working by Committee Isn't All Bad," *The Washington Post*, June 11, 1988.

Kentlands Estate, a proposed 352-acre development in Gaithersburg being developed by Joseph Alfandre & Co., Inc.

Liang, Ting-Peng, University of Illinois, "Model Management for Group Decision Support," *MIS Quarterly*, Volume 12, Number 4, December 1988, pp. 667-680.

Since models play a critical role in human decision processes, model management is considered a very important function for decision support. This article examines how model management systems can be designed to support group problem-solving. First, basic concepts of model management and functional requirements for group model management systems are described. Then, an architecture for group model management systems design is presented. Finally, major implementation issues are discussed.

Loy, Stephen L., William E. Pracht, James F. Courtney, Jr., "Effects of a Graphical Problem-Structuring Aid on Small Group Decision Making," *Proceedings of the Twentieth Annual Hawaii International Conference on Systems Sciences*, 1987, pp. 566-573.

A laboratory experiment was conducted to investigate the effectiveness of the problem-structuring aid in enhancing group decision-making quality and problem understanding in a semi-structured problem domain. Two commonly used group decision-making procedures--Nominal Group Technique (NGT) and Interacting Groups (IG)--were used to investigate the effects of the problem-structuring aid in an unstructured (IG) and a structured group setting (NGT). The results of the experiment indicate that group decision-making quality and problem understanding were enhanced by the use of the problem-structuring aid, and that these effects were not related to group problem-solving structure.

Mackett, David, National Oceanic and Atmospheric Administration, La Jolla, CA, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, February 1990.

Management Decision Center, Defense Systems Management College, Site Survey and Recommendations, Fort Belvoir, VA, 7 April 1989.

Mantei, Marilyn, University of Toronto, "Observation of Executives Using a Computer Supported Meeting Environment," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 153-166.

Designing interactive interfaces for individual usage is a significantly hard task that is being surmounted by evolving theory and hours of trial and error. The task of designing interactive interfaces for cooperative work and group decision making is even more difficult. Not only is it necessary to deal with the individual's cognitive processes and their model of the computer aided task, but also to build software to support human-human communication with all the underlying socialization and group dynamics that this communication implies. In the development of the Capture Lab, a computer supported meeting environment, guesswork was coupled with a study of human behavior in meetings both electronic and conventional. Added to these approaches was an extrapolation of existing research studies on noncomputerized meetings and a series of mini-experiments to test out various ideas about the design. The body of the paper describes the application of this mixture along with the design considerations at issue and the meeting behaviors we have since observed as a result of our design choices.

McCartney, Laton, "Brainstorming Problems With the Computer," *Dun's Business Month*, New York, NY, January 1987.

McCartt, Anne and John Rohrbaugh, The State University of New York at Albany, "Evaluating Group Decision Support System Effectiveness: A Performance Study of Decision Conferencing," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 243-253.

Effectiveness of decision making with decision conferences was explored by examining groups using the Decision Techtronics Group. Quantitative data were gathered through a self-administered survey of participants in 14 conferences. Perceived conference effectiveness was assessed with respect to a global outcome measure and 8 scales measuring the decision process effectiveness, based on the Competing Values Approach to organizational analysis. Differences in perceived conference success were related to:

(1) the proportion of participants who believed the conference resulted in a decision; and (2) the level of benefits derived from: full support of the structure or preference technology; the opportunity for full, extended discussion; development of an action plan; and expected resolution of the problem by the conference end.

McGee, John, and Howard Thomas, "Strategic Groups: Theory, Research and Taxonomy," *Strategic Management Journal*, Volume 7, 1986, pp. 141-160.

This paper discusses the concept of strategic groups, focusing upon the importance of intra-industry strategic groups in understanding differences across firms within an industry. The problems involved in identifying strategic groups within industries are examined through a comprehensive review of recent studies. It is demonstrated that much of the research has used surrogates for elements of a firm's strategic direction, e.g., vertical integration, product range, R&D expenditure, to suggest bases by which creative and sustainable groups are formed. The authors argue that certain theoretical concepts such as mobility barriers, isolating mechanisms and controllable variables provide much firmer bases for identifying strategic groups within industries. Thus, taxonomies for understanding the nature of strategic group formulation can be developed. Implications of the strategic group concept for such strategic issues as the structure-performance linkage, firm mobility, patterns of rivalry, industry evolution and firm growth are then examined. The paper concludes by indicating fruitful directions for strategic group research in the context of the strategic management field.

McHenry, William K.(Georgetown University), Kevin L. Lynch, and Seymour E. Goodman (University of Arizona), "Handling Textual Information in a GDSS Data Base: Experience with the Arizona Analyst Information System," *IEEE Proceedings of the Hawaii International Conference on System Science*, 21st, 5-8 January 1988, pp. 232-239.

Research on GDSS has mainly been focused on means to make decision meetings more productive, but decision making is a continuous process with interactions inside and outside of the meeting room. A GDSS data base must address general considerations of how information is stored and retrieved in decision environments. Much of this information is likely to be in the form of text, some of which is to *messy* that representing it in other forms is not worthwhile or is counterproductive. The Arizona Analyst Information System (AAIS) is a hypertext tool for entry, retrieval and analysis of textual information in a multi-user, multi-task, collaborative environment. This research examines the experience of using the AAIS for the cooperative creation, use, and maintenance of a large textual data base. The main questions considered are the performance of users as direct participants in the data base building process, and the way in which the AAIS design facilitates joint use of information.

National Science Foundation, Information Technology and Organizations Program, Special Initiative on Coordination Theory and Technology, November 1988, Announcement of Awards, November 1988.

Nunamaker, Jay F. and Douglas R. Vogel, University of Arizona, *Application of Electronic Meeting Systems to Military Organizations*, U.S. Army Institute for Research in Management Information Communications, and Computer Sciences (AIRMICS), ASQBG-A-89-031, Georgia Institute of Technology, 21 June 1989.

This report documents and categorizes representative Electronic Meeting System (EMS) environments to serve as a foundation for the effective application of these systems in military organizations. Aspects of system information (name, organization, category, cost, contact name), background (objective, history, future outlook), characteristics (tasks supported, facility, procedures and facilitation, software and hardware), and references for each system identified are included. Special attention is given to activities at the University of Arizona as an example of mature EMS environment. Key issues associated with effective EMS application in military organizations are identified. The report concludes with a general EMS bibliography. Visits and tasks at military organizations in conjunction with site visits and agendas of demonstrations using EMS software and facilities are appended.

Nunamaker, J.F., Editor, "Experience With and Future Challenges in Group Decision Support Systems (GDSS)," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 115-118.

Special Issue on GDSS.

Nunamaker, J.F., Doug Vogel, and Benn Konsynski, University of Arizona, "Interaction of Task and Technology to Support Large Groups," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 139-152.

There are multiple, and occasionally conflicting, perspectives regarding what Group Support Systems (GSS) are, what they should be, and what directions research related to them should take. The purpose of this paper is to focus on the factors involved in GSS, with particular attention to the ways in which these factors interact. A University of Arizona implementation of automated group decision support is described as an example of an established GSS, based upon a philosophy that recognizes the critical importance of environment, hardware and software to the successful operation of the system. Research conducted at University of Arizona facilities has involved experience with many groups brought together to address real problems. This research has resulted in identification of three interacting factors deemed to be essential to a successful GSS: user profile, task domain, and technology. Each of these is defined and its relationships with the others are described. Aspects of benefits to larger groups, task dynamics, interaction among group tasks and technology, multiple session benefits, integration of information technology and impacts upon group process also are explored. Multiple-methodological research approaches and opportunities for future research are addressed.

Nunamaker, Jay, Doug Vogel, Alan Heminger, and Ben Martz, University of Arizona, "Experiences at IBM with Group Support Systems: A Field Study," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 183-196.

Although numerous laboratory studies have been conducted, virtually no attention has been given to how well an operational Group Support System (GSS) functions in a real-world, organizational setting. This paper presents

the results of a GSS field study conducted at an IBM site. Data collected included session pre- and post-session questionnaires and facilitator observations plus followup interviews with managers and participants. Process and outcome effectiveness, efficiency, and user satisfaction were consistently higher for GSS compared to no automated support. Further, those who had used the automated system before consistently had a higher mean score on questions of process effectiveness. A comparison of man-hours expended resulted in a reported 56 percent savings attributable to GSS use. The overwhelmingly positive results of this field study contradict some laboratory experiment findings and support others. Directions for future field and experimental research to resolve apparent differences and provide further clarification are identified.

Nunamaker, J.F. (University of Arizona), Lynda M. Applegate, and Benn R. Konsynski (Harvard University), "Computer-Aided Deliberation: Model Management and Group Decision Support," *Operations Research*, Volume 36, Number 6, November-December 1988, pp. 826-848.

The paper highlights principles of group process as an important component of group activities in planning and policy making. The management of a variety of models utilized in organizational planning is discussed. Descriptions of the features and functions of the hardware and software environment along with scenarios for use of the environment illustrate critical issues in group deliberation. A particular model stakeholder identification and assumption surfacing is used to illustrate aspects of model management and planning process implementation. Findings of the group decision support system (GDSS) research are discussed in terms of anonymity of participation, facility design, need for multiple public screens, use of knowledge and data bases, communications network speed, methodology approach, software design, mixing of manual and electronic sessions, group size, composition, satisfaction of the users and model management systems. In general, the research results from experiments and case studies reflect our findings from observation of 40 groups.

Pace, Dale K. (The Johns Hopkins University APL) and David D. Moran (David Taylor Research Center), "Technology Gaming," *Naval Engineers Journal*, May 1989, pp. 240-250.

Wise investment of Department of Defense research and development (R&D) resources is becoming increasingly important. R&D policymakers and managers use a variety of means to guide their decisions. This paper discusses one of them: technology gaming. Technology gaming is a complement to traditional methods of technology forecasting, with technology gaming providing insights about constraints imposed upon advanced systems and technologies by operational environments and about their interactions with one another, drawing upon experiences acquired from several technology gaming endeavors in 1988, including the Technology Initiatives 88-Game (TIG-88) performed at the Naval War College under the joint-sponsership of the Office of Research, Development, and Acquisition in OpNav (OP-098) and the Naval War College.

Papadimitriou, Christos and John Tsitsiklis, "Intractable Problems in Control Theory," *Siam Journal of Control and Optimization*, Volume 24, Number 4, July 1986, pp. 639-654.

This paper is an attempt to understand the apparent intractability of problems in decentralized decision-making, using the concepts and methods of computational complexity. We first establish that the discrete version of an important paradigm for this area, proposed by Witsenhausen, is NP-complete, thus explaining the failures reported in the literature to attack it computationally. In the rest of the paper we show that the computational intractability of the discrete version of a control problem (the team decision problem in our particular example) can imply that there is no satisfactory (continuous) algorithm for the continuous version. To this end, we develop a theory of continuous algorithms and their complexity, and a quite general proof technique, which can provide interesting by themselves.

Parsons, Charles and Dennis Nagao, "Distributed Computer Supported Team Work: A Research Paradigm," *AIRMICS*, Report No. ASQB-GA-90-016, Georgia Institute of Technology, Atlanta, GA, December 1989.

The research in this report focuses on the viability of distributed, interacting, computer-supported team work and the factors that might impact the effective performance of such groups. Distributed refers to groups whose members are geographically separated; computer-supported refers to computer software that permits team members to *screen share* as well as exchange files; and interacting refers to groups working synchronously on a task. This report examines the concept of a distributed group; including different configurations of distributed team work and the restrictions they impose on group process.

Phillips, Lawrence, "Systems for Solutions," *Datamation Business*, April 1985, pp. 26-29.

This article examines five key problems that have limited the usefulness of decision support systems for senior executives:

- All decisions are about things that will happen in the future, but there are no data about the future.
- Computers can't assess uncertainty for unique events.
- Computers do not provide information about nonquantifiable, soft objectives.
- Computers can't specify what tradeoffs should be made among conflicting objectives.
- Computers can't form preferences.

The author recommends combining information technology with preference technology in the form of decision conferences to help executives make decisions quicker and more effectively.

Pieptea, Dan R., Evan Anderson, "Price and Value of Decision Support Systems," *MIS Quarterly*, December 1987, pp. 515-527.

A two-dimensional framework for Decision Support Systems (DSS) cost-benefit analysis is proposed. One dimension reflects the degree to which the supported decision is structured, the level of managerial activity, the level of uncertainty and the source of information used, while the second dimension classifies DSS based on the phase of the supported decision according to Simon's model for the decision-making process. The review of the current literature reconciles some of the contradictory findings in the DSS cost-benefit literature, and shows that the adequacy of the valuation method depends on the attributes of the system. The main DSS valuation issues are identified, and the paper discusses the potential gap between price

(determined by estimated costs or the market) and the value (which is subjective). The magnitude of this gap is found to be correlated with the extent to which the supported decisions are structured.

Pinsonneault, Alainl and Kenneth L. Kraemer, University of California, "The Impact of Technological Support on Groups: An Assessment of the Empirical Research," *Decision Support Systems, The International Journal,* Volume 5, Number 2, North-Holland, June 1989, pp. 197-216.

In this paper, we analyze the empirical findings on the impacts of technological support on groups. We define and differentiate two broad technological support systems for group process: Group Decision Support Systems (GDSS), and Group Communication Support Systems (GCSS). We then present a framework and method for analyzing the impacts of such information systems on groups. We develop the framework from the literature of organization behavior and group psychology and apply it to literature of MIS. We then review the empirical research and findings concerned with the impacts of GDSS and GCSS on groups, and we compare and contrast these findings. Finally, we conclude by discussing the implications of our analysis on the focus of attention and design of future research. Five Major implications stem from our analysis: (1) there is lack of research on some important *formal* factors of groups; (2) there is a paucity of research on the impacts of GDSS and GCSS on the informal dimension of groups; (3) there is a need to move away from laboratory settings to field study in organization settings, with *real* managers; (4) more research is needed on stages of group development and on how they affect the impacts of GDSS and GCSS on groups; and (5) more research is needed to understand how the structure imposed by the technological supports affect group processes.

Poole, M. S. and G. L. DeSanctis, "Group Decision Making and Group Decision Support Systems: A 3-Year Plan for the GDSS Research Project," *Management Information Systems Research Center School of Management,* MISRC-WP-8-02, Working Paper Series, September 1987, pp. 1-79.

The purpose of this project is to develop and test the theory necessary for the orderly progress of research and application of group decision support systems (GDSS). The project undertakes a comprehensive investigation of GDSS by a team of researchers from the fields of management science, speech communication, and public policy studies at the University of Minnesota. Group decision support systems are "social technologies," designed to aid organizational groups in complex decision situations. The effects of these technologies are of interest in their own right; they are also interesting because they throw group processes into sharp relief, permitting insights into the nature of group work.

Poole, Marshall S., Michael Holmes, and Gerardine DeSanctis, University of Minnesota, "Conflict Management and Group Decision Support Systems," *Association for Computing Machinery (ACM),* September 1988, pp. 227-243.

Reilly, Anthony J. and John E. Jones, "Team-Building," *The 1974 Annual Handbook for Group Facilitators,* Reference 6, 1974 University Associates Publishers, Inc., pp. 227-237.

If a creature came from another planet to study earth civilization and returned to give a report, a *fair witness* about us would be, "They do almost everything in groups. They grow up in groups, play in groups, live in

groups, and work in groups." Facilitators working in organizations understand that the basic building blocks of human systems are interdependent groups of people, or teams.

Some of the most exciting things about organization development (OD) are the many different, potentially useful activities and interventions that are available in this field. Many of these are oriented toward the individual working in the organization: career planning, one-to-one coaching and counseling, job enrichments, life planning. In this focus, the individual looks at himself in relation to his organization.

Another class of interventions, however--equally significant to an organization's growth--focuses on groups within the organization. This direction includes such activities as problem-solving at the group level, confrontation meetings, diagnostic meetings, and goal-setting sessions.

Rein, Gail L. and Clarence A. Ellis, "rIBIS: A Real-Time Group Hypertext System," Microelectronics and Computer Technology (MCC), Technical Report Number STP-095-90, Software Technology Program, Austin, TX, March 1990.

This paper describes rIBIS, a real-time group hypertext system, which allows a distributed set of users to simultaneously browse and edit multiple views of a hypertext network. At any time, rIBIS users can switch back and forth between tightly coupled and loosely coupled interaction modes. The paper describes the high-level architecture, underlying object classes, and user interface of the rIBIS system. Early use of the rIBIS system by a software system design team suggests that users' acceptance increases as they continue to use the tool. We conclude that rIBIS effectiveness is affected by both people and implementation issues.

Richman, Louis S., "Technology - Software Catches the Team Spirit," *Fortune*, June 8, 1987, pp. 125-136.

New computer programs may soon change the way groups of people work together--and start delivering the long-awaited payoff from automation.

"Groupware" aims to place the computer squarely in the middle of communications among managers, technicians, and anyone else who interacts in groups, revolutionizing the way they work. Even meetings will become more effective as today's low-tech conference rooms turn into multimedia "war rooms" controlled by software that keeps everything on course.

Organizational planning and design decisions are typically quite complex, involving multiple decision makers with diverse perspectives, competing priorities, and large amounts of information. A group decision support system (GDSS) is of great benefit in these situations by using information technology to structure, facilitate and document the decision making process and by providing a framework for coalescing input from various decision makers and offering feedback on the implications of their assumptions. A case study of a decision conference (an intensive form of GDSS) held for the New York State Insurance Department demonstrates the advantages of decision modeling and information technologies used to improve the decision-making process, and also exemplifies the distinction between decision support systems (DSS) and GDSS.

Schuman, S.P., University at Albany, "Computer-Assisted Conferences for Organization Planning and Design," Planning and Design in Management of Business and Organization (*1987 International Conference on Planning and Decision Theory*), Boston, MA, 17-20 August 1987, pp. 75-81.

Organizational planning and design decisions are typically complex, involving multiple decision makers with diverse perspectives, competing priorities, and large amounts of information. A GDSS is of great benefit in these situations by using information technology to structure, facilitate and document the decision making process and by providing a framework for coalescing input from various decision makers and offering feedback on the implications of their assumptions. A case study of a decision conference (an intensive form of GDSS) held for the New York State Insurance Department demonstrates the advantages of decision conferencing as a combination of group facilitation techniques, decision modeling and information technologies used to improve the decision-making process, and also exemplifies the distinction between decision support systems (DSS) and GDSS.

Schweiger, David M., William R. Sandberg, and James W. Ragan, "Group Approaches for Improving Strategic Decision Making: A Comparative Analysis of Dialectical Inquiry, Devil's Advocacy, and Consensus," *Academy of Management Journal*, Volume 29, Number 1, 1986, pp. 51-71.

This laboratory study compared the effectiveness of the dialectical inquiry, devil's advocacy, and consensus approaches to strategic decision making by groups. Results showed that both dialectical inquiry and devil's advocacy led to higher quality recommendations and assumptions than consensus. Dialectical inquiry was also more effective than devil's advocacy with respect to the quality of assumptions brought to the surface. However, subjects in the consensus groups expressed more satisfaction and desire to continue to work with their groups and greater acceptance of their groups' decisions than did subjects in either of the two other types of group studied.

Schuman, S.P., *Computer-Assisted Conferences for Organization Planning and Design*, Rockefeller College of Public Affairs and Policy, University at Albany, Albany, NY, pp. 75-81.

Organizational planning and design decisions are typically complex, involving multiple decision makers with diverse perspectives, competing priorities, and large amounts of information. A group decision support system (GDSS) is of great benefit in these situations by using information technology to structure, facilitate and document the decision making process and by providing a framework for coalescing input from various decision makers and offering feedback on the implications of their assumptions. A case study of a decision conference (an intensive form of GDSS) held for the New York State Insurance Department demonstrates the advantages of decision conferencing as a combination of group facilitation techniques, decision modeling and information technologies used to improve the decision-making process, and also exemplifies the distinction between decision support systems (DSS) and GDSS.

Simon, Herbert A., "Decision Making and Problem Solving," *INTERFACES 17*, 5 September-October 1987, pp. 11-31.

The MS/OR community has, as its common mission, the development of tools and procedures to improve problem solving and decision making.

This report discusses the advances needed to combine human thinking with intelligent machines to achieve a more productive society. Areas of high potential include research in expert systems, conflict resolution, agenda setting, decision making in an organizational setting, and empirical studies of individual behavior. The resources currently being applied to research in decision making and problem solving are modest and are not commensurate with the opportunities or the human resources available for exploiting them.

Smith, Jill Y. (University of Denver) and Michael T. Vanecek (University of North Texas), "Computer Conferencing and Task-Oriented Decisions: Complications for GDS," North-Holland, *Information and Management 14*, 1988, pp. 123-132.

An experiment was used to compare the impact of two very current communication modes during task-oriented group decision making activities. Subjects completed a task-oriented decision making activity using either face-to-face (simultaneous) or computer conferencing (nonsimultaneous) communication modes.

Sprague, Ralph H., Jr., "A Framework for the Development of Decision Support Systems," *MIS Quarterly*, December 1980, pp. 1-26.

This article proposes a framework to explore the nature, scope, and content of the evolving topic of Decision Support Systems (DSS). The first part of the framework considers (a) three levels of technology which have been designated DSS, (b) the developmental approach that is evolving for the creation of a DSS, and (c) the roles of several key types of people in the building and use of a DSS. The second part develops a descriptive model to assess the performance objectives and the capabilities of a DSS as viewed by three of the major participants in their continued development and use. The final section outlines several issues in the future growth and development of a DSS as a potentially valuable type of information system in organizations.

Stabell, Charles B., "Towards a Theory of Decision Support," *DSS-88 Transactions*, Eighth International Conference on Decision Support Systems, Boston, MA, 1988, pp. 160-170.

This paper develops elements for a theory that deals with context of decision support. The paper focuses on two aspects of such a theory of decision support: (1) How organization shapes decision situations, decision roles and decision making behavior and (2) how managers view their decision making roles and alternative decision support arrangements.

Two distinguishing aspects of this effort to develop a theory of decision support are given. First, the theory attempts to provide a perspective on the context of decision support that is descriptively useful. Descriptively useful means that it should also have prescriptive implications. Second, the outline should indicate that further work on a theory of decision support will to be large extent be work on decision making in organizations as both a cognitive and organizational phenomenon.

Stefik, Mark, D. Bobrow, G. Soter, S. Lanning, and D. Tatar, "WYSIWIS Revised: Early Experiences with Multiuser Interfaces," Xerox Palo Alto Research Center, *ACM Transactions on Office Information Systems*, Volume 5, Number 2, April 1987, pp 147-167.

WYSIWIS (What You See Is What I See) is a foundational abstraction for multiuser interfaces that expresses many of the characteristics of a chalkboard in face-to-face meetings. In its strictest interpretation, it means that everyone can also see the same written information and also see where anyone else is pointing. In our attempts to build software support for collaboration in meetings, we have discovered that WYSIWIS is crucial, yet too inflexible when strictly enforced. This paper is about the design issues and choices that arose in our first generation of meeting tools based on WYSIWIS. Several examples of multiuser interfaces that start from this abstraction are presented. These tools illustrate that there are inherent conflicts between the needs of a group and the needs of individuals, since user interfaces compete for the same display space and meeting time. To help minimize the effect of these conflicts, constraints were relaxed along four key dimensions of WYSIWIS: display space, time of display, subgroup population, and congruence of view. Meeting tools must be designed to support the changing needs of information sharing during process transitions, as subgroups are formed and dissolved, as individuals shift their focus of activity, and as the group shifts from multiple parallel activities to a single focused activity and back again.

Stefik, Mark, and John Seely Brown, "Toward Portable Ideas," Xerox Palo Alto Research Center, 25 March 1988, pp 1-20.

The key to effective teamwork is in the interaction of properly externalized ideas. To promote responsiveness in next generation organizations we propose active and sharable workspaces for working together to develop information. These can be realized in seamless tools for computer-mediated conversation that extend from offices to coffee lounges to formal meeting rooms.

Stefik, Mark, Gregg Foster, Daniel G. Bobrow, Kenneth Kahn, Stan Lanning, and Lucy Suchman, "Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings," *Communications of the ACM*, Volume 30, Number 1, January 1987, pp. 32-47.

Although individual use of computers is fairly widespread, in meetings we tend to leave them behind. At Xerox PARC, an experimental meeting room called the Colab has been created to study computer support of collaborative problem solving in face-to-face meetings. The long-term goal is to understand how to build computer tools to make meetings more effective.

Straub, Detmar W., Jr. and Renee Beauclair, "A New Dimension to Decision Support: Organizational Planning Made Easy with GDSS," *Data Management*, July 1987, pp. 11, 12, and 20.

Computer conferencing software supporting decision rooms; software packages such as FORUM; and distributed network tools are all organization group decision support systems enhancement tools, termed GDSS.

GDSS is broadly defined as any technology that is used to enhance group decision making in an organization. As with individual Decision Support Systems (DSSs), Group Decision Support Systems (GDSSs) are designed to provide tools and support for decision making.

This paper describes the results of a national survey on Group Decision Support Systems. Three generic types of GDSS structure are covered:

- Face-to-face conferences (computerized decision rooms).
- Interfaced computer conference (electronic mail).

- Face-to-face teleconferencing (decision rooms in remote areas with electronic links.

Straub, Detmar W., Jr. (University of Minnesota) and Renee A. Beauclair (University of Louisville), "Current and Future Uses of GDSS Technology: Report on a Recent Empirical Study," *Proceedings of the Twenty-First Annual Hawaii International Conference on System Sciences*, Decision Support and Knowledge Based Systems Track, 5-8 January 1988, IEEE, pp. 149-158.

> Over the last decade, GDSS technology has made enormous technical advances. It has also been studied from conceptual and design perspectives. This work considers how GDSS can be used to improve group decisions in face-to-face conferencing (*decision rooms*) remote site teleconferencing, and remote/local computer conferencing. These prospects have been aided by advances in telecommunications technology and GDSS seems poised for successful integration into modern organizations.
>
> This study looks at the actual ways in which GDSS is currently being utilized. The framework for the study was derived from DeSanctis and Gallupe's work; a survey of 135 randomly selected DPMA members was used as the sample base. Based on preliminary data analysis, it appears that GDS are slowly being introduced and supported by IS departments and that this pattern will be the trend for the immediate future as well. Data analysis will be completed in the near future, but analytical procedures are delineated in the paper. These procedures take two primary forms. Descriptive statistics based on the study data will assess the extent to which organizations are increasing their commitment to GDSS and which current implementations are heaviest in each of the GDSS types. Factor analysis of respondent data will also be used to assess task-group usage of GDSS, task groups including: (1) planning; (2) administrative; and (3) data analysis tasks. The study will also assess whether usage of GDSS varies significantly with certain organizational size variables.
>
> A better understanding of these relationships should greatly assist IS managers in allocating resources to this new technology and in making the case for GDSS to top management. It should also help GDSS software developers formulate new design features.

Sutherland, David and Robert Crosslin (University of Maryland), "GDSS: Factors in a Software Implementation," North-Holland, *Information and Management 16*, 1989, pp. 93-103.

> The implementation of a GDSS is a major consideration of *networked* organizations. This article presents the results of a study that focused on an interactive software implementation of the Analytic Hierarchy Process (AHP) as a GDSS. State policy makers used the AHP to ascertain factors critical to their success. Four different implementations were used: the results of these indicate that varied inconsistency levels will be experienced, based on how it is implemented. Recommendations for future implementation of GDSS are given.

Thomas, Lewis, Memorial Sloan-Kettering Cancer Center, "The Ambassador Essay: On Committees," *TWA Ambassador*, August 1979, pp. 22-23.

Treat, Charlie, Office of Program Planning and Evaluation, U.S Department of Commerce, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, Washington, DC, February 1990.

Turner, Bob, Organizational Planning and Development Division, Office of Human Resource Management, FAA, viewgraphs, presented at the DSMC Mini-Conference on Group Decision Technology in the Government, Washington, DC, February 1990.

Turner, Bob, *FAA Group Station 2000, A Concept Paper*, Federal Aviation Administration, Washington, DC, November 1989.

Turoff, Murray, and Starr Rosanne Hiltz, "Computer Support for Group Versus Individual Decisions," *IEEE Transactions on Communications*, Volume COM-30, Number 1, January 1982, pp. 82-91.

> Most decision support systems use computers to support interaction between individuals and a structured model, analytic routine, or a database. However, many problems are unstructured or at best semistructured, and are dealt with by groups of managers within organizations. When dealing with nonroutine problems, the decision-making groups are often geographically and organizationally dispersed. Thus, a decision support system for these groups must include communications, structured to support the decision-making process among members of the group.
>
> This paper gives several examples of computerized conferencing systems (CCS's) which have served as a group decision support systems (DSS's). In addition, the results of a controlled experiment comparing the process and outcome of group decision-making in a face-to-face versus a CC mode are discussed. Finally, preliminary results are presented from a second controlled experiment which explored how a CCS may best be structured to serve as a group DSS for a specific type of managerial task.

Valacich, Joseph S., Douglas R. Vogel, and J. F. Nunamaker, Jr., "A Semantic Guided Interface for Knowledge Base Supported GDSS," *DSS-88 Transactions*, Eighth International Conference on Decision Support Systems, Boston, MA, 1988, pp. 45-56.

> Group Decision Support Systems (GDSS) have emerged to provide automated support for group deliberation and decision making. Historically, technological complexity and lack of support for end user interaction have hindered effective use of knowledge bases in conjunction with group deliberation and decision making. This paper describes a system that incorporates a semantic guided interface designed to overcome user apprehension to using Knowledge Base Management Systems developed for use with University of Arizona PlexCenter group decision support software. The semantic guided interface supports input, query, presentation, and reporting functions in conjunction with effective individual and group utilization. Time spent by group members extracting information is reduced in an atmosphere of enhanced user appreciation of knowledge base capabilities without sacrificing system integrity. Presentation of issues associated with complex questions is facilitated for group deliberation. The end result is powerful integrated support for group decision making.

Valusek, LCol. John R. "Skip", "Adaptive Design of DSSs: A User Perspective," *DSS-88 Transactions*, Eighth International Conference on Decision Support Systems, Boston, MA, 1988, pp. 105-112.

> The developers of information systems recognize that decision support systems cannot be developed using a traditional systems development approach. Instead, an "adaptive design" approach is recommended to permit decision processes to be more adequately modeled and supported. Although many people espouse this approach, there has been little research

of what is necessary to accomplish this radical change to the way we perform information engineering. The "start small and grow" approach impacts both user's and builder's roles in the process. DSS generators are evolving to support the builder's role. The purpose of this research is to investigate the process of adaptive design from a user's perspective of requirements evolution. The goal is to define the user's role in adaptive design and to apply technology to facilitate that role.

Warfield, J. N., and A. N. Christakis, "Dimensionality," *Systems Research*, Volume 4, Number 2, 1987, pp. 127-137.

New definitions of *dimensionality* and *dimension* are set forth that dominate older definitions. Dominance means not that older interpretations are violated, but that the sense of the new interpretation extends substantially the sense of older interpretations, thereby opening up the use of the term in a much broader class of situations.

Among the benefits of the new interpretation of dimensionality are: greater understanding of situations, greater effectiveness in describing situations, more lucid descriptions, better system designs, substantive cross-discipline problem-solving activities that cannot now be carried out in a common framework, and the potential for a more coherent community of scholars.

Warfield, John N., "Dimensionality," *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics*, 14-17 October 1986, pp. 1118-1121.

New definitions of "dimension" and "dimensionality" are set forth that dominate older definitions. Among the benefits of the new interpretations of these terms are: greater effectiveness in describing and understanding systems, ability to accommodate quantitative and qualitative factors in the same framework, and the possibility of disciplining the design and management of complex systems, to avoid calamities of the type that occur too frequently in modern society.

Warfield, John N., George Mason University, "The Magical Number Three-Plus or Minus Zero," *Cybernetics and Systems: An International Journal*, Volume 19, 1988, pp. 339-358.

Research by Miller (1956) and Simon (1974) shed light on limitations of human beings in carrying out various operations on information. Both authors concluded that the span of immediate recall of people is in the range between five and nine, Simon concluding that it is closer to five than to nine. Both authors approached the issues through results of experimentation on human subjects, and neither connected any of the work to ideas from mathematical logic having to do with the organization of information. Although this prior work was of considerable significance, its full significance will never be recognized until it is possible to relate it to human performance in such society-steering roles as those filled by powerful managers, designers of large systems, and public opinion makers, for the purpose of improving significantly the quality of what they do. The work of Simon and Miller is reinterpreted here from the perspective of mathematical logic, with special emphasis on means of structuring information using the lattice as the organizing unit. Two different types of lattice are examined, and their connection to human capacity to integrate information and make decisions is interpreted in the light of the work of Simon and Miller. It is concluded that there are substantive reasons for viewing three as the magical number, especially in system design theory.

Warfield, John N., "Complementary Relations and Map Reading," Appendix 2, *IEEE Transactions on Systems, Man, and Cybernetics*, Volume SMC-10, Number 6, June 1980, pp. 285-291.

> When a group has applied the interpretive structure modeling process to develop a map of a theme or issue, they typically inspect visually the map they have produced to see whether it is instructively satisfactory. While this practice is useful and may play a role in map amendment, a more thorough approach is recommended. The working space of the map consists of the ordered element pairs belonging to the Cartesian product S x SI, where S is the set of elements modeled through a contextual relation represented by the binary relation R. In a systematic modeling effort, it is desirable to establish the completeness of the relation R without requiring mathematical sophistication on the part of the modeling group. (If R is not complete, only part of the knowledge germaine to the working space is embedded in the model.) Moreover, some of the useful knowledge content of the working space may only be implicit in R. If the modeling group is to take full advantage of the knowledge embedded in a map, it is essential that the group understand a systematic procedure for reading maps. Such a procedure is presented, and it is postulated that the group knows how to use it. A method is then developed whereby a computer can generate, from a knowledge of R, two additional maps (one of which can be null in special cases) such that: (a) if R is complete, the group can determine content of the working space from the map of R and the two additional maps; or (b) if R is not complete, the group can be cued by the computer to supply the additional information required to establish completeness of R. With the aid of this method, it is shown that the entire content of the working space can be read from the final set of (at most) three maps for each primary relation R being explored.

Warfield, John N., "Some Principles of Knowledge Organization," Appendix 3, *IEEE Transactions on Systems, Man, and Cybernetics*, Volume SMC-9, Number 6, June 1979, pp. 317-325.

> The substantive complexity of a complex system or issue can be diminished by the introduction of structural complexity to describe that system or issue. To minimize the negative impact of the introduction of structural complexity, graphics should be translatable into prose. To assure that this can be done, it is necessary to define a metalanguage that is not only appropriate for use in modeling, but also is adequate to bridge the structural gap to applications. The availability of well-defined structural types helps minimize the impact of structural complexity. Several structural types are defined, and a principle of definition is set forth as a reasonable basis for choosing and distinguishing these types. The set inclusion relation is the most critical one in the metalanguage of structuring in problem definition, because of its key role in the definition of terms, hence of systems or issues. To assure that this relation can be constructively applied, especially with graphics representations, mappings are developed that provide a basis to convert poorly structured information into well-structured information, suitable for a translatable graphic presentation.

Warfield, John N., "Priority Structures," Appendix 4, *IEEE Transactions on Systems, Man, and Cybernetics*, Volume SMC-10, Number 10, October 1980, pp. 642-645

> The development of priority structures represents a growing area of application of interpretive structural modeling (ISM). However, structures

that have been produced in applications are defective in some respects. Priority structures necessarily fall into one of three structural types: linear hierarchies, linear mixed structures, or nonlinear regular hierarchies. Structures that do not fall into one of these three categories are defective. Structural defects are readily correctable through the use of appropriate amendment procedures.

Warfield, John N., "Crossing Theory and Hierarchy Mapping," Appendix 5, *IEEE Transactions on Systems, Man, and Cybernetics*, Volume SMC-7, Number 7, July 1977, pp. 505-523.

Techniques are introduced which are applicable to machine construction of digraph maps. These techniques are oriented toward reduction of the number of crossings in a map as a means of improving the readability of hierarchical structures. Permuting, psi-factoring, rotation, twirling, and absorbing are among the techniques considered. Examples are given to illustrate these techniques. When these and related procedures are fully developed for use with machine-interactive processes, they will facilitate group modeling efforts.

Watabe, Kazuo (C&C Systems Research Labs, Kanagawa, Japan), Clyde W. Holsapple, and Andrew B. Whinston (Purdue University), "Coordinator Support in a *Nemawashi* Decision Process."

There is a growing body of literature concerned with computerized support of distributed decision making. However, support for the distinctive Japanese way of distributed decision making has yet to be considered. At the heart of this decision making approach is *nemawashi* and the attendant *ringi*. A key role in a *nemawashi* decision process is that of a coordinator who endeavors to achieve a consensus, prepares informal and formal documents, and circulates the latter for consent. Here, we introduce a very flexible mathematical model to support the *nemawashi* process. This descriptive model, based in part on MCDM notions, accommodates a variety of coordinator strategies pertinent to different decision situations by considering participant preferences and influences. Such a model provides the foundation for understanding, designing, and implementing coordinator support systems to facilitate distributed decision making in Japanese organizations.

Watson, Richard T. (Western Australia College of Advanced Education), Gerardine DeSanctis, and Marshall S. Poole (University of Minnesota), "Using a GDSS to Facilitate Group Consensus: Some Intended and Unintended Consequences," *MIS Quarterly*, September 1988, pp. 463-477.

A cumulative body of experimental research is emerging that examines the ability of computer technology to support the processes and outcomes of small group meetings. For the most part the GDSS effort has been concerned with demonstrating the usefulness of the technology in planning and decision-making situations where the quality of the meeting's outcomes can be objectively assessed. In many decision situations, however, there is no objective measure of decision quality available. Rather, the group must reconcile difference sin opinion, personal preference, or judgment and achieve consensus about a particular mode of action. As a contribution to the accumulating research on GDSS, the current study examines the effects of a GDSS in resolving conflicts of personal preference. In a task requiring resolution of competing personal preferences, 82 groups--the largest sample size in the GDSS literature to date--were randomly assigned to one of three

experiment conditions: (1) a computer-based support system (GDSS); (2) a manual, paper and pencil, support system; or (3) no support whatsoever. Groups were either of size 3 or 4 persons. Use of the GDSS was expected to facilitate democratic participation in group discussion, move group members toward agreement with one another, and result in a high level of satisfaction with the group decision process. While several of the intended effects of the technology were observed, the groups experienced some unintended consequences as a result of using the GDSS. In general, the GDSS technology appeared to offer some advantage over no support, but little advantage over the pencil and paper method of supporting group discussion.

Weiss, Howard J. (Temple University) and J. Yael Assous (AT&T Bell Labs), "Reduction in Problem Size for Ranking Alternatives in Group Decision-Making," *Computational Operations Research*, Volume 14, Number 1, 1987, pp. 55-65.

We examine the problem of finding a group ranking of alternatives, based on the rankings of several raters, that minimizes the number of reversals with respect to the raters' rankings. We characterize the possible structure of an optimal solution. This leads to a graph-theoretical method that preorders the alternatives, thereby subdividing the problem into problems of smaller sizes. The smaller size problems can then be solved using either branch and bound techniques or existing heuristics. Applications to complete and incomplete rankings are presented.

Wood, Fred, "Integrated Support, Advanced Systems for Program Appraisal: Prospects for General Systems Decision Support Centers in the USA," *Project Appraisal*, Volume 2, Number 2, June 1987, pp. 97-101.

Advances in information technology and systems science are opening up new opportunities for improved decision support systems at the highest levels of the U.S. government. Federal agencies already make extensive use of computer-based decision support, including spreadsheet software, decision analysis models, forecasting techniques and (sometimes) decision conferences and computer conferences. Federal agencies are also increasingly using electronic data bases, remote-sensing data from satellites, advanced computational capability, and advanced computer graphics and displays.

These developments are rarely integrated together and applied in direct support of top-level agency and government-wide decision-making. Realization of improved top-level decision support could be achieved through a synthesis of technical, informational, and analytical advances utilizing general systems and cybernetics concepts to create what might be called general systems decision support centers or systems (GSDSS). GSDSS could help the government cope with increasingly complex national and world problems, and to anticipate better the impacts of proposed programs and projects.

Zigurs, Llze (University of Colorado), M. Scott Poole, and Gerardine L. DeSanctis (University of Minnesota), "A Study of Influence in Computer-Mediated Group Decision Making," *MIS Quarterly*, Volume 12, Number 4, December 1988, pp. 625-644.

An emerging body of research in GDSS provides evidence that computer technology can and does impact the quality of decision making in groups. Most GDSS research is oriented toward examining the effects of a computer system on group outcomes, typically decision quality or group consensus, with the process itself often treated as a *black box*. The research reported in this article addresses the need for a closer, micro-level examination of group process. An important group variable, namely influence behavior, was isolated and examined at various levels and by multiple methods.

A model of specific GDSS effects on influence behavior was developed, based on an information exchange view of decision making and on the impact of a GDSS as a communication channel. Based on the research questions of interest in the study, several propositions and hypotheses were advanced and empirically tested on a specific implementation of a GDSS. Results were analyzed both quantitatively and qualitatively. The major empirical findings of the study showed no significant difference between the overall amount of influence behavior attempted in computer-supported versus unsupported groups, although significant differences were found in the pattern of influence behaviors, i.e., the different types of behaviors used. In addition, the distribution of influence behavior was more even in GDSS groups than in unsupported groups on one of two measures used. Empirical findings partially supported the research model, with indications that decision-making groups need more active guidance in understanding how to adapt computer support technology to their view of decision-making processes.

Zigurs, Llze,University of Colorado, "Interaction Analysis in GDSS Research: Description of an Experience and Some Recommendations," *Decision Support Systems, The International Journal*, Volume 5, Number 2, North-Holland, June 1989, pp. 233-241.

An emerging body of research in Group Decision Support Systems (GDSS) provides evidence that computer technology impacts the quality of decision making in groups. Most GDSS research focuses on the effects of computer support on outcomes, such as decision quality, commitment, or consensus. This article discusses the analysis of group process, rather than outcomes, via the technique of interaction analysis. Interaction analysis provides a micro-level examination of verbal interaction. The application and extension of interaction analysis in GDSS research is reviewed and illustrated.

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